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PERIMETER GROUNDWATER CONTAINMENT SYSTEM RD/RA WORK PLAN

AMERICAN CHEMICAL SERVICE, INC. NPL SITE GRIFFITH, INDIANA

Prepared For:

ACS RD/RA EXECUTIVE COMMITTEE

April 1996

EPA Region 5 Records Ctr.
268164

Project No.: 4077.0060

Montgomery Watson
4525 South Wasatch Blvd., Suite 200
Salt Lake City, UT 84124

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EXECUTIVE SUMMARY

This Perimeter Groundwater Containment System (PGCS) Remedial Design/Remedial Action (RD/RA) Work Plan was prepared by Montgomery Watson Americas, Inc. (Montgomery Watson) on behalf of certain respondents in response to the Unilateral Administrative Order (UAO) issued by the United States Environmental Protection Agency (U.S. EPA), Region V on September 30, 1994. The purpose of this RD/RA Work Plan is to document the strategy and approach for performing the design, construction, operation, maintenance, and monitoring of the PGCS. The PGCS is one component of the overall remedy for the Site as described in the UAO and Statement of Work (SOW) issued by U.S. EPA. The purpose of the PGCS is to prevent further migration of contaminants in the upper aquifer groundwater from a portion of the ACS site to adjacent properties. It is not the intent of the PGCS to treat all contaminated groundwater at the site. Areas not collected and treated with the PGCS will be addressed during the non-expedited remedial design and remedial action, as necessary and appropriate. The PGCS water treatment plant will also be used to treat groundwater, decontamination water, condensate water and other aqueous phase material generated by pilot tests and site investigations conducted during the pre-design activities.

This RD/RA Work Plan was developed based on the expressed desire of both U.S. EPA and the Indiana Department of Environmental Management (IDEM) to have components of the remedy designed and constructed on an expedited basis. The respondents expressed a similar desire and voluntarily agreed to design and construct, on an expedited basis, a groundwater collection and treatment system to prevent off-site migration of contaminants in the upper aquifer along the northwestern perimeter of the Site. The work described in this RD/RA Work Plan is consistent with the goals of the UAO for the Site.

Actions that will expedite the implementation of the groundwater containment and treatment system are:

- Fast-Tracking the design process (i.e., limiting the number of submittals and reviews)
- Utilizing the design/build approach
- Designing a flexible treatment system
- Obtaining (to the extent possible and reasonable) agency assistance in obtaining approvals/permits.

Based on a review of existing groundwater data, treatment processes being considered include air stripping, steam stripping, UV/oxidation, chemical precipitation, biologically activated carbon (BAC), and carbon adsorption. Treatment for metals will be part of each treatment alternative. To further evaluate treatment options, an engineering analysis of groundwater treatment alternatives will be completed once water quality data are received and discharge limitations are established. In addition, samples of contaminated groundwater have been sent to potential vendors of select treatment systems (i.e., advanced oxidation) for testing of effectiveness with Site-specific contaminants and analysis of cost of treatment.

The remedial design will include a Site reconnaissance to identify potential locations for treatment facilities and potential discharge locations, and to locate utility tie-ins, etc. A pump test and waste area groundwater characterization were conducted to determine the aquifer characteristics and provide data to facilitate design of the pump and treat system. The pump test was conducted on the west side of the Site and is described in Appendix A. The waste area groundwater characterization consisted of obtaining samples of groundwater from within the Still Bottoms Pond and Off-Site Containment Area using a Geoprobe (see Figure 1 for geoprobe sample locations). The samples were then analyzed for a broad range of contaminants. The results of the testing will be used to evaluate various water treatment technologies.

It is important to note that in order to meet the expedited design schedule, some deviations from the SOW will be need to be made. For instance, this RD/RA Work Plan describes only two design submittals (an intermediate design at the 50% design stage and final design at the 100% design stage) instead of the four design submittals described in the SOW. In addition, implementation of the PGCS is being accomplished utilizing the design/build approach, and as such the details of each design submittal will be slightly different than that described in the SOW. Throughout the work plan, deviations from the SOW will be highlighted.

The actual implementation of the PGCS will be accomplished in three phases:

- Construction
- Start-up/Prove-out
- Operation, Maintenance and Monitoring

A Performance Standard Verification Plan will be prepared and submitted as a part of the intermediate and final design. The plan will document the procedures and reporting requirements to assess the performance of the groundwater containment and treatment systems. Record drawings and the Final Completion of Construction Report will be prepared at the completion of the remedial action. The RD/RA Work Plan includes a schedule and list of project deliverables as a part of the plan.

Appendices to the RD/RA Work Plan include procedures used for conducting the pump test and standard operating procedures for the installation of soil borings and monitoring wells.

Section 1

1.0 INTRODUCTION

1.1 PURPOSE

This Remedial Design/Remedial Action (RD/RA) Work Plan for the Perimeter Groundwater Containment System (PGCS) was prepared by Montgomery Watson Americas, Inc. (Montgomery Watson) on behalf of the Respondents to the Unilateral Administrative (UAO) Order issued by the United Stated Environmental Protection Agency (U.S. EPA), Region V, on September 30, 1992, for the American Chemical Service, Inc. (ACS) Site (the Site) in Griffith, Indiana. The definition of the Site is described on Page 3 of the Record of Decision. The purpose of the RD/RA Work Plan is to document the overall strategy and approach for performing the design, construction, operation, maintenance and monitoring of the PGCS. The PGCS is one component of the overall remedy for the Site as described in the UAO and Statement of Work (SOW) issued by U.S. EPA. The purpose of the PGCS is to prevent further migration of contaminants in the upper aquifer groundwater from a portion of the ACS Site to adjacent properties. The PGCS is not intended to remediate the full extent of groundwater contamination. Additional groundwater remediation activities would be addressed during the non-expedited remedial design and remedial action phases, as appropriate. The PGCS water treatment plant will also be used to treat groundwater, decontamination water, condensate water and other aqueous wastes generated by pilot tests and Site investigations conducted during the pre-design activities.

The Record of Decision (ROD) for the Site, provides a remedy for the Site which includes the following components:

- Ground water pumping and treatment system to dewater the Site and to contain the contaminant plume with subsequent discharge of the treated ground water to surface water and wetlands;

- Excavation of approximately 400 buried drums in the On-Site Containment Area for off-site incineration;

- Excavation of buried waste materials and treatment by low-temperature thermal treatment (LTTT);

- On-site treatment or off-site disposal of treatment condensate;

- Vapor emission control during excavation and possible immobilization of inorganic contaminants after LTTT;
- Off-site disposal of miscellaneous debris;
- In-situ vapor extraction pilot study of buried waste in the On-Site Area;
- In-situ vapor extraction of contaminated soils;
- Continued evaluation and monitoring of wetlands and, if necessary, remediation;
- Long term groundwater monitoring;
- Fencing the Site and implementation of deed and access restrictions and deed notices; and
- Private well sampling with possible well closures or groundwater use advisories.

During meetings held early in 1995 with the Respondents, U.S. EPA, and Indiana Department of Environmental Management (IDEM), the agencies expressed a desire to have some components of the remedy designed and constructed on an expedited basis. The Respondents expressed a similar desire and voluntarily agreed to expedite the design and construction of a groundwater collection and treatment system to prevent off-site migration of contaminants along the northwestern perimeter of the Site. This PGCS will be a component of the overall remedy described above. As described below, the work associated with implementing the PGCS is consistent with the UAO and the goals of the ROD for the Site.

The ROD for the Site (ROD, Page 16) defined the following remedial action goals:

1. To ensure that public health and the environment are not exposed to cancer and non-cancer risks greater than the acceptable risk range from drinking water, soils, buried drums/liquid wastes/sludges, or other substances from the ACS Site

2. To restore ground water to applicable state and federal standards

3. To reduce the migration of contaminants off site through water, soils or other media

4. To reduce the potential for erosion and possible migration of contaminants via Site surface water and sediments, including areas surrounding Turkey Creek.

Installation of the PGCS will immediately prevent further off-site migration of contaminants in the upper aquifer from a portion of the ACS Site to adjacent properties (Goal 3). The sooner the PGCS is operational, the sooner migration of groundwater contamination will be controlled. It will also be the first step in remediating groundwater to applicable state and federal standards (Goal 2). Any treated groundwater which is discharged to the wetlands will be done in a manner which will reduce the potential for erosion and possible migration of contaminants via surface water (Goal 4). Finally, the system will help to ensure that public health and the environment are not exposed to cancer and non-cancer risks greater than the acceptable risk range (Goal 1). The design and installation of the PGCS is not intended to remediate the full extent of groundwater contamination at the Site, however, it partially addresses all four remedial action goals. Therefore, the work is consistent with the remedial action goals of the UAO and Statement of Work (SOW) and accomplishes them on an expedited basis.

The PGCS will be a part of the overall strategy for meeting the groundwater performance standards, which are defined in the ROD. Other components of the strategy will include the design and installation of subsurface barrier walls for the waste areas and the design and installation of other systems to meet the performance standards at the compliance boundary, which is defined in the ROD. The barrier walls will primarily control horizontal groundwater contaminant migration, and control some surface seeps in the Off-Site Containment Area and Still Bottoms Pond Area until the final remedy is implemented. The final alignment of the barrier walls around the waste areas is still being determined and will depend on the results of investigative efforts. The sooner the waste areas are isolated, the sooner contaminant migration will be controlled. Groundwater will be pumped from within the barrier walls to maintain an inward gradient. The treatment plant designed as a part of the PGCS will be used to treat groundwater from within the barrier walls.

The PGCS treatment system will also be used to facilitate the pilot tests provided for by the ROD. Some of the pilot tests required by the ROD will be conducted in discrete test cells, which require that dewatering be completed prior to the start of each pilot test. The dewatering of the pilot test cells must be completed on schedule to keep the remedial design on schedule. For further information on the pilot testing, see the Pre-Design Work Plan. Other components of the groundwater strategy are described in separate work plans. Because the PGCS will be designed and installed on an expedited basis, data gathered during operation of the system will be used to design and install subsequent components of the overall groundwater strategy.

1.2 GENERAL APPROACH

The PGCS will be designed and constructed on an expedited schedule to contain contaminated groundwater, and provide a mechanism for the on-site treatment of pilot test- and investigation-derived water. The design effort will include a pump test and some limited groundwater sampling.

The following actions will expedite the implementation of the groundwater containment and treatment systems:

- Fast-Track of the Design Process
- Utilization of the Design/Build Approach
- Design of a Flexible Treatment System
- Assistance with Approvals/Permits

Fast-Track Design Process. The SOW (Page 19, Task 3) allows, subject to approval by U.S. EPA, the Respondent to submit more than one set of design submittals reflecting different components of the remedial action. On January 6, 1995, the Respondents discussed the schedule and submittals for the RD/RA of the PGCS. To expedite the design phase, a design workshop will be held so that all parties can be involved with the approach, schedule, technology selection, and other major decisions. In addition, design packages will only be submitted at the 50 percent, and 100 percent design stages. It has been assumed that agency reviews will be consistent with the schedule discussed in Chapter 4.

Utilize Design/Build Approach. The design/build approach will significantly reduce the overall time to implement the extraction and treatment facilities. Because one company takes responsibility for providing a system that meets the performance objectives, it is not necessary to produce drawings and specifications to the level of detail typically required for soliciting bids. This streamlines the design phase and eliminates the bid period for construction.

Design of a Flexible Treatment System. Although the initial purpose of the treatment system will be to treat groundwater extracted from the perimeter containment system, it will also be used to treat waters generated from other remedial activities at the Site. Consequently, the technology selected for implementation at the Site must be easily expandable and must be able to handle a wide range of influent characteristics. By designing a treatment system with a high degree of flexibility and capability of expansion, less time will need to be spent defining the actual influent characteristics and the associated uncertainties. Instead, a system with significantly more capacity than is required for just the PGCS will be designed, and it will be modified later to accommodate future waters generated by other activities at the Site.

Approvals/Permits Assistance. Although permits will not be obtained, the ACS PRPs must assure that the PGCS complies with all substantive requirements of the relevant and appropriate permitting authorities. The assistance of the U.S. EPA and Indiana Department of Environmental Management (IDEM) may be required to streamline the regulatory agency review process regarding the approvals or requirements that may be needed to build and operate the PGCS.

Section 2

MONTGOMERY WATSON

2.0 REMEDIAL DESIGN

The design of the Perimeter Groundwater Containment System will be accomplished in three phases:

- Design Investigation
- Intermediate Design
- Final Design

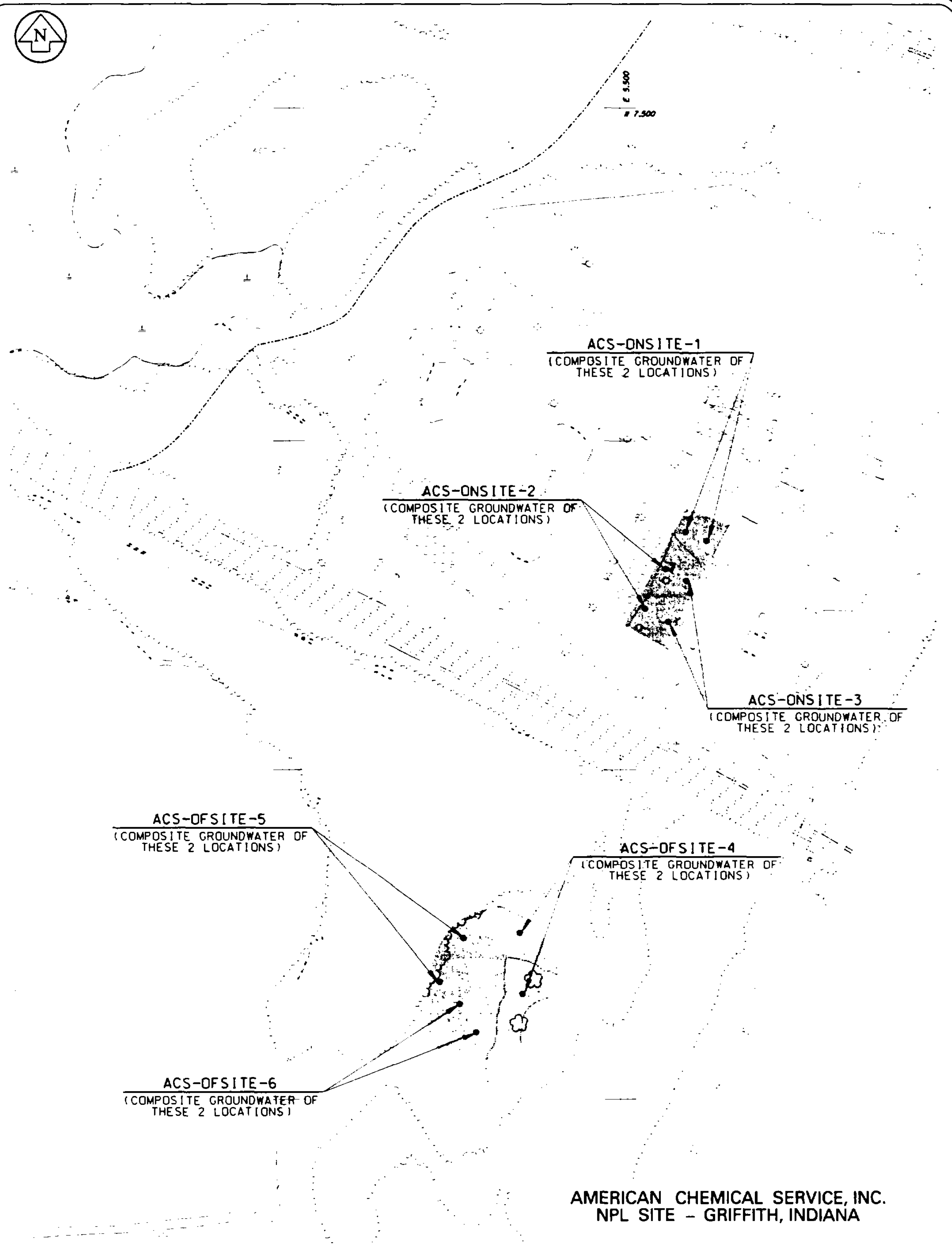
2.1 DESIGN INVESTIGATION

Additional information must be collected on an expedited basis to support the design effort. The design investigation activities are discussed below.

Site Reconnaissance. A Site visit will be conducted to identify potential locations for the treatment facilities and potential discharge locations, to locate a power supply and water supply, establish piping routing, etc. In addition, it may be necessary to survey some areas of the Site and to collect soil samples for geotechnical analysis if such data does not exist for the area selected for siting the treatment system.

Pump Test/Waste Area Sampling. These activities include performing pump tests, and characterizing the general quality (mineral content, total organic carbon, alkalinity, etc.) of the groundwater (i.e., pore fluids) from the waste areas. Samples of groundwater from each of the waste areas will be collected using the Geoprobe method. Geoprobe sample locations are shown in Figure 1. Approximately six locations at each of the two waste areas (i.e., the Off-site Containment Area and the Still Bottoms/Treatment Lagoon Area) will be sampled and these subsamples will be composited into three samples from each of the waste areas. The six composite samples (i.e., three from each area) will be analyzed for the parameters listed in Table 1. The samples will be pumped from the Geoprobe at low flow rates using disposable tubing.

The pump test and Geoprobe sampling approach are described in Appendix A. Soil boring and well installation Standard Operating Procedures (SOPs) are included in Appendix B. Montgomery Watson's Pump Test SOP is provided in Appendix C.



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NPL SITE – GRIFFITH, INDIANA

SOURCE CHARACTERIZATION (GEOPROBE SAMPLE LOCATIONS)

FIGURE 1

TABLE 1

SAMPLE TYPE AND ESTIMATED SAMPLE NUMBERS
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Sample[1] Matrix	No. of Samples	Field Duplicates	Trip[2] Blanks	MS/MSD[3]	Lab Parameters	Field Parameters	Lab[4] Methods
AQUIFER TEST							
Groundwater	5	–	1	–	Volatiles	pH, Spec. Cond.	SW846
	3	–	–	–	Semi-Volatiles	Temp., D.O.	SW846
	3	–	–	–	P.P. Metals		EPA-600
	3	–	–	–	Ca, Mg, Na, K, Cl, Fe		EPA-600
	3	–	–	–	Sulfate, Alkalinity, Hardness		EPA-600
	3	–	–	–	Total P, Oil & Grease		EPA-600
	3	–	–	–	TOC, BOD, COD, TSS, TDS, TKN		EPA-600
SOURCE CHARACTERIZATION							
Leachate (medium to high concentration)	6	–	1	–	Volatiles	pH, Spec. Cond.	SW846
	6	–	–	–	Semi-Volatiles	Temp., D.O.	SW846
	6	–	–	–	P.P. Metals		EPA-600
	6	–	–	–	Ca, Mg, Na, K, Cl, Fe		EPA-600
	6	–	–	–	Sulfate, Alkalinity, Hardness		EPA-600
	6	–	–	–	Total P, Oil & Grease		EPA-600
	6	–	–	–	TOC, BOD, COD, TSS, TDS, TKN		EPA-600

Notes:

1. Unless otherwise noted, samples will be considered low concentration, and will be packaged and shipped accordingly.
2. A trip blank for VOC analysis will be included with each cooler shipped for aqueous (groundwater) samples. Trip blanks are not included in the total number of samples.
3. MS/MSD will be run at a ratio of 1 per 20 samples.
4. Lab Methods refer to laboratory parameters. For specific methods see Table A-2.

2.2 INTERMEDIATE DESIGN

The approach to the Intermediate Design is to determine the treatment objectives, perform an engineering analysis to evaluate and select treatment technologies, meet with the agencies to discuss the design process, and then prepare the design documents for agencies review. These activities are discussed below.

Permitting. Before the groundwater treatment system can be selected, it is essential that the discharge limitations for the treated water be established. In addition, it will be necessary to identify any air discharge restrictions for the treatment system. For on-site activities permits will not be necessary, however, substantive requirements of permits will have to be met. Permits may be required for off-site activities. Montgomery Watson will make the necessary contacts and prepare the necessary documentation to initiate the permitting processes. To the extent possible and reasonable, U.S. EPA and IDEM assistance in contacting and meeting with personnel from the respective permitting authorities will be utilized to further expedite the process.

Alternatives Analysis. An engineering analysis of two or three treatment alternatives will be performed to finalize the treatment train. The analysis will involve establishing design criteria, preliminary sizing of equipment, and developing budget level construction and operation and maintenance costs.

Design Workshop. Several design workshops were held and it is anticipated that additional design workshops will be held through the process to discuss various aspects of the design. Attendees will include Montgomery Watson project team members, ACS Technical Committee, U.S. EPA, and IDEM. The workshops are intended to provide a forum for all parties to express their expectations regarding the treatment system and the content of the deliverables. The workshops are utilized to discuss design schedule, establish design freezes (dates after which conceptual design decisions will not change so that detailed design can be completed), and to develop a mechanism for obtaining early consensus on time critical design decisions.

50 Percent Design. A deliverable that represents the 50 percent completion stage of the design shall be submitted for review by U.S. EPA and IDEM. The submittal will address many of the requirements of the preliminary and intermediate design phases as stated in the SOW. These requirements are as follows:

- Preliminary plans, drawings and sketches, including design calculations

  - Process flow diagram

  - Process and instrumentation diagrams

  - Well construction details

  - Structural plan

  - Mechanical plan and sections

  - Draft Health & Safety (H&S) Plan addendum

  - Drafts of the Operation & Maintenance (O&M) Plan, Contingency Plan and Performance Standard Verification Plan (PSVP)

- Results of treatability studies and additional field sampling

  - Results of the pump tests
  - Results of treatability studies

- Design assumptions and parameters, including design restrictions, process performance criteria, appropriate unit processes for the treatment train, and expected removal or treatment efficiencies for both the process and waste (concentration and volume)

  - A design analysis presenting design criteria, assumptions, calculations

- Proposed cleanup verification methods, including compliance with Applicable or Relevant and Appropriate Requirements (ARARs),

  - The Performance Standard for the PGCS trench and dewatering system will be gradient control

  - Effluent limitations for the discharge of the PGCS treatment plant

- Proposed siting/locations of processes/construction activity

  - Civil site plan and yard piping

- Expected long-term monitoring and operation requirements

- Real estate, easement and permit requirements

- Preliminary construction schedule, including contracting strategy

  -Preliminary estimate of construction and operation and maintenance costs

  -Preliminary construction schedule

- Draft Construction Quality Assurance Plan.

Certain items listed in the SOW were either not appropriate for the PGCS, or were inconsistent with the design/build approach. The items listed in the SOW, but not included in the submittal are as follows:

- Technical specifications. Specifications are used by the engineer to define for the contractor exactly what materials, equipment and means of installation are required. Since Montgomery Watson is serving as both the engineer and the contractor for this project, detailed technical specifications are not needed to solicit bids and procure contractors. Consequently, none shall be included in the submittal. Specifications for certain materials and equipment shall be included in the purchase orders for those items as appropriate.

- QAPP addendum and Field Sampling Plan (FSP). These documents will not be prepared since the construction of the PGCS will not require any environmental sampling and analysis.

2.3 FINAL DESIGN

100 Percent Design. A deliverable that represents the 100% completion stage of the design will be submitted for review and approval by U.S. EPA and IDEM. At this time, it is anticipated that the construction process will be underway for certain components (long lead time equipment) that have been approved by U.S. EPA and IDEM. The Final Design will address all comments made to the Intermediate Design and will include reproducible drawings and specifications as needed for the construction. The submittal will include the following:

- Final Performance Standard Verification Plan
- Final Construction Quality Assurance Plan
- Final Health and Safety Plan
- Draft Contingency Plan
- Draft Operation and Maintenance Plan
- Refined Capital and Operation and Maintenance Cost Estimate to reflect the detail presented in the final design
- Final Project Schedule for the Construction and Implementation of the Remedial Action which identifies timing for initiation and completion of critical path tasks. Specific components to be constructed as part of the Remedial Action will be considered by the Respondents to be critical path items and will be addressed independent of each other to facilitate expediting of the Remedial Action if feasible. The final project schedule submitted as part of the Final Design will include specific dates for completion of this phase of the project and major milestones.

A draft of the Contingency Plan shall be included as part of the O&M plan. Although the ROD and SOW require a Final Contingency Plan to be submitted with the 100 percent design, it will not be possible to finalize the document until the operations personnel are selected. The Contingency Plan will be finalized during the construction phase along with the O&M Plan.

As stated for the Intermediate Design, certain items listed in the SOW were either not appropriate for the PGCS or were inconsistent with the design/build approach. The items listed in the SOW, but not intended to be included in the Final Design Submittal are as follows:

- Technical specifications

- Final QAPP addendum and Final Field Sampling Plan (FSP). These documents will not be prepared since the construction of the PGCS will not require any environmental sampling and analysis.

The exclusion of the two items listed above is a departure from the ROD and the UAO.

Section 3

MONTGOMERY WATSON

3.0 REMEDIAL ACTION

Implementation of the Perimeter Groundwater Containment System will be accomplished in three phases:

- Construction
- Start-up and Prove-out
- Operation, Maintenance, and Monitoring

3.1 CONSTRUCTION

The construction phase will commence following submission of the Intermediate Design. The U.S. EPA and IDEM are expected to review the Intermediate Design submittal for major problems as it is anticipated that general agreement on the important design issues will be reached at the design work shops. Specific construction tasks that will be performed include:

Pre-Construction Activities. The Respondents will participate with the U.S. EPA and the IDEM in a preconstruction inspection and meeting to:

- Review methods for documenting and reporting inspection data;
- Review methods for distributing and storing documents and reports;
- Review work area security and safety protocol;
- Discuss any appropriate modifications of the construction quality assurance plan so that site-specific considerations are addressed; and,
- Conduct a Site walk to verify that the design criteria, plans and specifications are understood and to review material and equipment storage locations.

The pre-construction activities to be conducted include establishing documentation, testing and inspection procedures; holding a pre-construction inspection and meeting with the construction personnel and the agencies; assuring access to the project site; obtaining any pre-construction permits that are required; coordinating potential utility interferences;

establishing procedures for handling wastes; and developing a detailed construction schedule.

Construction. Construction of the PGCS shall include the following major activities:

- Mobilization to Site
- Clearing and Grubbing
- Road Construction
- Building Construction
- Utilities Installation
- Treatment Equipment Installation
- Extraction Trench Installation
- PGCS Start-Up
- Site Restoration
- Preparation and Submission of Prefinal Construction Inspection Report
- Preparation and Submission of Final Construction Inspection Report
- Preparation and Submission of Notice of Attainment of Inward Gradient
- Preparation and Submission of Completion of Remedial Action Report

Construction Management. Management of the construction will involve maintaining construction progress schedules and expenditure curves, preparing monthly progress reports, and holding weekly construction progress meetings.

Construction Closeout. Construction closeout activities include demobilizing, preparing the Contractor's Certification of Completion, conducting a prefinal inspection, developing a punch list, conducting a final inspection, issuing a Notice of Completion, and issuing final payment.

3.2 START-UP AND PROVE-OUT

After construction is substantially complete, start-up and prove-out of the facilities will be conducted. A plan and schedule for the start-up and prove-out will be prepared when the construction is approximately 75 percent complete. Within 15 days after the Respondents make a preliminary determination that construction is complete, the Respondents will notify the U.S. EPA and IDEM for the purposes of conducting a prefinal inspection. The prefinal inspection will consist of a walk-through inspection of the entire treatment facility with the U.S. EPA and the IDEM. The inspection is to determine whether the construction is complete and consistent with the contract documents and the remedial action. Any outstanding construction items discovered during the inspection will be identified and noted. Additionally, treatment equipment will be operationally tested by the Respondents. The Respondents will certify that the equipment has performed to meet the purpose and intent of the specifications. Retesting will be completed where deficiencies are revealed. The prefinal inspection report will outline the outstanding construction items, actions required to resolve items, completion date for these items, and a proposed date for a final inspection.

Within 15 days after completion of any work identified in the prefinal inspection report, the Respondents will notify the U.S. EPA and the IDEM for the purposes of conducting a final inspection. The final inspection will consist of a walk-through inspection of the facility by the U.S. EPA, the IDEM and the Respondents. The prefinal inspection report will be used as checklist with the final inspection focusing on the outstanding construction items identified in the prefinal inspection. Confirmation will be made that outstanding items have been resolved.

3.3 OPERATION, MAINTENANCE, AND MONITORING

Continued operation, maintenance, and monitoring (O&M) of the extraction and treatment systems will need to be conducted to satisfy the remedial action objective. The scope of these activities will be defined in the O&M Plan to be developed as part of the RD/RA effort. Items included in the manual are discussed below. Maintenance and sampling of monitoring wells will also be conducted, and the details of this effort will be described in the Performance Standard Verification Plan.

3.4 REMEDIAL ACTION DELIVERABLES

The major deliverables to be submitted to U.S. EPA and IDEM during the remedial action phase include:

- Preconstruction Inspection

- Monthly Construction Progress Reports (to be a part of the Monthly Progress Report required by the UAO)

- Operations and Maintenance Plan

- Performance Standard Verification Plan
- Pre-Final Inspection
- Final Inspection
- Record Drawings
- Final Construction Report
- Completion of Remedial Action Report

The format and content of the Monthly Construction Progress Report will be established in the pre-construction meeting. The remaining deliverables are described in the following sections.

Operations and Maintenance Plan. An Operations and Maintenance (O&M) Plan will be prepared to address initial start-up and long-term O&M requirements of Perimeter Groundwater Containment System. A prefinal of the plan will be submitted with the Final Design submittal as stated previously. The final O&M Plan shall be submitted to U.S. EPA and IDEM prior to the pre-final construction inspection in accordance with the approved construction schedule. The plan shall be composed of the following elements:

1. Description of normal operations and maintenance;

    a. Description of tasks for operation
    b. Description of tasks for maintenance
    c. Description of prescribed treatment or operation conditions
    d. Schedule showing frequency of each O&M task

2. Description of potential operating problems;

    a. Description and analysis of potential operation problems
    b. Sources of information regarding problems and
    c. Common and/or anticipated remedies

3. Description of routine monitoring and laboratory testing;

   a. Description of monitoring tasks

   b. Description of required data collection, laboratory tests and their interpretation

   c. Required quality assurance and quality control

   d. Schedule of monitoring frequency and procedures for a petition to EPA and the IDEM to reduce the frequency of or discontinue monitoring, and

   e. Description of verification sampling procedures if Cleanup or Performance Standards are exceeded in routine monitoring

4. Description of alternate O&M;

   a. Should systems fail, alternate procedures to prevent release or threatened releases of hazardous substances, pollutants or contaminants which may endanger public health and the environment or exceed performance standards, and

   b. Analysis of vulnerability and additional resource requirements should a failure occur

5. Corrective Action;

   a. Description of corrective action to be implemented in the event that cleanup or performance standards are exceeded, and

   b. Schedule for implementing these corrective actions

6. Safety Plan

   a. Description of precautions, of necessary equipment, etc. for Site personnel, and

b. Safety tasks required in the event of systems failure

7. Description of equipment, and

   a. Equipment identification
   b. Installation of monitoring components
   c. Maintenance of Site equipment and
   d. Replacement schedule for equipment and installed components

8. Records and reporting mechanisms required

   a. Daily operating logs
   b. Laboratory records
   c. Mechanism for reporting emergencies
   d. Personnel and maintenance records, and
   e. Monthly/annual reports to the U.S. EPA and IDEM

Performance Standard Verification Plan. The purpose of the Performance Standard Verification Plan (PSVP) is to provide a mechanism to ensure that both short-term and long-term Performance Standards for the Remedial Action are met. The activities required to monitor and report on the performance of this aspect of the remedy will be presented in the Performance Standard Verification Plan. A draft of the PSVP will be submitted with the Final Design as stated earlier in this work plan. The PSVP will include a QAPP addendum, HSP addendum, and FSP. The plan will describe the number and location of wells to be monitored for water level and water quality, and the effluent monitoring sampling protocols, in addition to documentation procedures and reporting requirements. The plan will address monitoring to assess the performance of the perimeter groundwater containment system and performance of the treatment system.

QAPP. A Quality Assurance Project Plan (QAPP) will be prepared to describe the sample analysis and data handling for samples collected as part of the PSV program. The QAPP shall be consistent with the requirements of the EPA Contract Lab Program (CLP) for laboratories proposed outside the CLP. The QAPP shall include the following:

1. Project Description

    a. Facility Location History
    b. Past Data Collection Activity
    c. Project Scope
    d. Sample Network Design
    e. Parameters to be Tested and Frequency
    f. Project Schedule

2. Project Organization and Responsibility

3. Quality Assurance Objective for Measurement Data

    a. Level of Quality Control Effort
    b. Accuracy, Precision and Sensitivity of Analysis
    c. Completeness, Representativeness and Comparability

4. Sampling Procedures

5. Sample Custody

    a. Field Specific Custody Procedures
    b. Laboratory Chain of Custody Procedures

6. Calibration Procedures and Frequency

    a. Field Instruments/Equipment
    b. Laboratory Instruments

7. Analytical Procedures

    a. Non-Contract Laboratory Program Analytical Methods
    b. Field Screening and Analytical Protocol
    c. Laboratory Procedures

8. Internal Quality Control Checks

   a. Field Measurements
   b. Laboratory Analysis

9. Data Reduction, Validation, and Reporting

   a. Data Reduction
   b. Data Validation
   c. Data Reporting

10. Performance and System Audits

   a. Internal Audits of Field Activity
   b. Internal Laboratory Audit
   c. External Field Audit
   d. External Laboratory Audit

11. Preventive Maintenance

   a. Routine Preventative Maintenance Procedures and Schedules
   b. Field Instruments/Equipment
   c. Laboratory Instruments

12. Specific Routine Procedures to Assess Data Precision, Accuracy, and Completeness

   a. Field Measurement Data
   b. Laboratory Data

13. Corrective Action

   a. Sample Collection/Field Measurement
   b. Laboratory Analysis

14. Quality Assurance Reports to Management

Health and Safety Plan. Health and Safety Plans (HSP) which are designed to protect on-site personnel and area residents from physical, chemical and all other hazards posed by this component of the remedy will be developed. Two HSPs will be prepared: one for the PGCS construction and one for the activities associated with the PSV program for the PGCS. The safety plans shall develop the performance levels and criteria necessary to address the following areas:

1. Facility Description
2. Access Control
3. Personnel
4. Levels of Protection
5. Safe Work Practices and Safe Guards
6. Medical Surveillance
7. Personal and Environmental Air Monitoring
8. Personal Protective Equipment
9. Personal Hygiene
10. Decontamination—Personal and Equipment Site Work Zones
11. Contaminant Control
12. Contingency and Emergency Planning
13. Logs, Reports, and Recordkeeping

The safety plan shall follow EPA and State guidance and all OSHA requirements as outlined in 29 CFR 1910 and 1926.

Contingency Plan. A Contingency Plan describing procedures to be used in the event of an accident or emergency at the Site shall be developed. The draft Contingency Plan shall be submitted with the prefinal design and the final Contingency Plan shall be submitted with the Final O&M Plan. The Contingency Plan shall include, at a minimum, the following:

1. Name of the person or entity responsible for responding in the event of an emergency incident.

2. Plan and date(s) for meeting(s) with the local community, including local, State and Federal agencies involved in the cleanup, as well as local emergency squads and hospitals.

3. First aid medical information.

4. Air Monitoring Plan (if applicable).

Field Sampling Plan. A Field Sampling Plan will be developed to describe the sampling to be conducted as part of the PSV program. The Field Sampling Plan shall supplement the QAPP and address all sample collection activities. Sample collection activities shall include, at a minimum, the following elements:

1. Site Background
2. Sampling Objectives
3. Sample Location and Frequency
4. Sample Description
5. Sampling Equipment and Procedures
6. Sample Handling and Analysis

Construction Quality Assurance Plan. A Construction Quality Assurance Plan (CQAP) describing the site-specific components of the quality assurance program which ensure that the completed project meets or exceeds all design criteria, plans, and specifications shall be developed. The draft CQAP shall be submitted with the prefinal design and the final CQAP shall be submitted with the final design. The CQAP shall contain, at a minimum, the following elements:

1. Responsibilities and authorities of all organizations and key personnel involved in the design and construction of the Remedial Action.

2. Qualifications of the Quality Assurance Official to demonstrate that this individual possesses the training and experience necessary to fulfill the identified responsibilities.

3. Protocols for sampling and testing used to monitor construction.

4. Identification of proposed quality assurance sampling activities including the sample size, locations, frequency of testing, acceptance and rejection data sheets, problem identification and corrective measures reports, evaluation reports, acceptance reports, and final documentation.

A description of the provisions for final storage of all records consistent with the requirements of the UAO shall be included.

5. Reporting requirements for CQAP activities shall be described in detail in the CQAP. This shall include such items as daily summary reports, inspection data sheets, problem identification and corrective measures reports, design acceptance reports, and final documentation. Provisions for the final storage of all records shall be presented in the CQAP.

Prefinal Inspection. Within 15 days after Respondents make a preliminary determination that construction is complete, the Respondents shall notify U.S. EPA and IDEM for the purposes of conducting a prefinal inspection. The prefinal inspection will consist of a walk-through inspection of the entire PGCS Facility with U.S. EPA and IDEM. The inspection is to determine whether the construction is complete and consistent with the contract documents and the Remedial Action. Any outstanding construction items discovered during the inspection will be identified and noted. Additionally, treatment equipment shall be operationally tested by the Respondents. The Respondents will certify that the equipment has performed to meet the purpose and intent of the specifications. Retesting will be completed where deficiencies are revealed. The prefinal inspection report will outline the outstanding construction items, actions and a proposed date for final inspection.

Final Inspection. Within 15 days after completion of any work identified in the prefinal inspection report, the Respondents shall notify U.S. EPA and IDEM for the purposes of conducting a final inspection. The final inspection will consist of a walk-through inspection of the PGCS Facility by U.S. EPA, IDEM, and the Respondents. The prefinal inspection report shall be used as a checklist with the final inspection focusing on the outstanding construction items identified in the prefinal inspection. Confirmation will be made that outstanding items have been resolved.

Record Drawings. After start-up, the Final Design drawings will be updated to include any changes during construction.

Final Construction Report. A Final Construction Report will be prepared within 30 days after a successful final inspection. The report will describe the facilities and explain significant changes from the original design. The report will include the record drawings signed and stamped by a professional engineer. In the report, a registered professional engineer and the Respondent's Project Coordinator shall state that the construction has been completed in accordance with the design and specifications. The report shall contain the following statement, signed by a responsible corporate official of a Settling Defendant or the Respondent's Project Coordinator:

"To the best of my knowledge, after thorough investigation, I certify that the information contained in or accompanying this submission is true, accurate and complete. I am aware there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations."

Completion of Remedial Action Report. A completion of Remedial Action Report shall be submitted by the Respondents when construction is complete and performance standards have been attained and where O&M requirements will continue to be performed.

Section 4

MONTGOMERY WATSON

4.0 SCHEDULE

Since the commencement of activities associated with the design and construction of the PGCS are dependent upon approval of this work plan, it is not possible to establish "hard" dates at this time. The detailed schedule for the PGCS will, therefore, be submitted as part of the master schedule for the overall ACS project which will be updated to reflect actual dates that approvals are granted.

In general, however, the schedule for the PGCS is as follows: The 50 Percent (Intermediate) Design Submittal shall be submitted within 21 days of receipt of U.S. EPA's approval of the PGCS RD/RA Work Plan. The 100 Percent (Final) Design Submittal shall be submitted within 21 days of the U.S. EPA's comments on the 50 Percent Design Submittal. The construction schedule shall be established in the 100 Percent Design Submittal and construction shall follow the approved schedule contained therein.

The Final Performance Standard Verification Plan and Final Construction Quality Assurance Plan shall be submitted within 21 days of receipt of U.S. EPA comments on the draft submittals. The Final Contingency Plan will be finalized with the O&M Plan.

Appendix A

MONTGOMERY WATSON

APPENDIX A

PUMP TEST
AND WASTE AREA SAMPLING
PROCEDURES

APPENDIX A

GROUNDWATER PUMPING TEST
AND
WASTE AREA SAMPLING

1.1 PUMPING TEST

An aquifer pumping test will be performed to collect physical and chemical information to design the Perimeter Groundwater Containment System. The test will consist of pumping an extraction well, collecting water samples from the pumping well effluent, and monitoring water level declines in the pumping well and in nearby wells and piezometers. The water level data will be used to provide an estimate of the aquifer permeability, specific capacity, and well efficiency. From these characteristics, the well spacing, well construction, and groundwater pumping rates will be determined.

Water samples (grab) will be collected directly from the sampling port on the discharge line of the submersible pump in the pumping well during the test to provide an estimate of the contaminant concentrations and the general water chemistry. Standard Chain-of-Custody preservation, sample management and holding time procedures and restrictions will be observed. There will be no field filtration of any of the samples (i.e., "Total" analyses will be performed). The groundwater sampling results will be used to design the treatment needed to achieve the discharge standards. The general chemistry data are also needed to select the well construction materials and estimate the potential for encrustation or other clogging (e.g., biofouling) of the water intake screen.

The pump test well (designated EW1) will be located along the west perimeter of ACS in an area of VOC impacted groundwater. In addition, the well will be located so that existing monitoring wells (MW9, MW10 and MW13) and piezometers (P27 and P38) can be used for water level monitoring during the test. Two additional piezometer (P50 and P51) will be constructed for the pump test. These piezometers will fully screen the aquifer (approximately 20 ft), which will improve the accuracy of the pump test analysis. The test boreholes for the extraction well (EW1) and the piezometers (P50 and P51) will be drilled using hollow-stem augers at the proposed well location and split-spoon samples will be collected continuously from the ground surface to the top of the clay. A minimum of two samples will be submitted for grain size analysis. Figure A1 shows the location of the monitoring wells and piezometers used in the pump test.

The extraction well will fully screen the saturated portion of the aquifer (approximately 20 ft) and be constructed of 6-inch inside diameter (ID) PVC well screen and riser pipe (stick-up completion). The piezometer will be constructed of 2-inch ID PVC well screen and riser pipe. The filter (or natural sand pack) will be placed to a depth 2 ft above the top of the screen. Two feet of fine sand will be placed on top of the filter pack and a bentonite clay seal above the fine sand. A steel protective casing will be installed and secured with concrete. The extraction well and piezometer will be bored, constructed and developed following Montgomery Watson's standard operating procedures (Appendix B), and a step test performed. The development is needed to remove fine particles from the well. The step test will be conducted no sooner than 72 hours before the pump test is scheduled to begin, to determine the specific capacity and well efficiency, and determine the flow rate for the pump test.

The pump test will be conducted according to Montgomery Watson's standard operating procedure (Appendix C). The extraction well will be continuously pumped for 24 hours at a constant rate. Water level recovery measurements will be collected for up to 24 to 48 hours. The extraction well and the observation wells will be monitored with a combination of pressure transducers with continuous recording data loggers and manual measurements. Background water level measurement will be collected three days prior to the pump test and through the recovery period of the pump test.

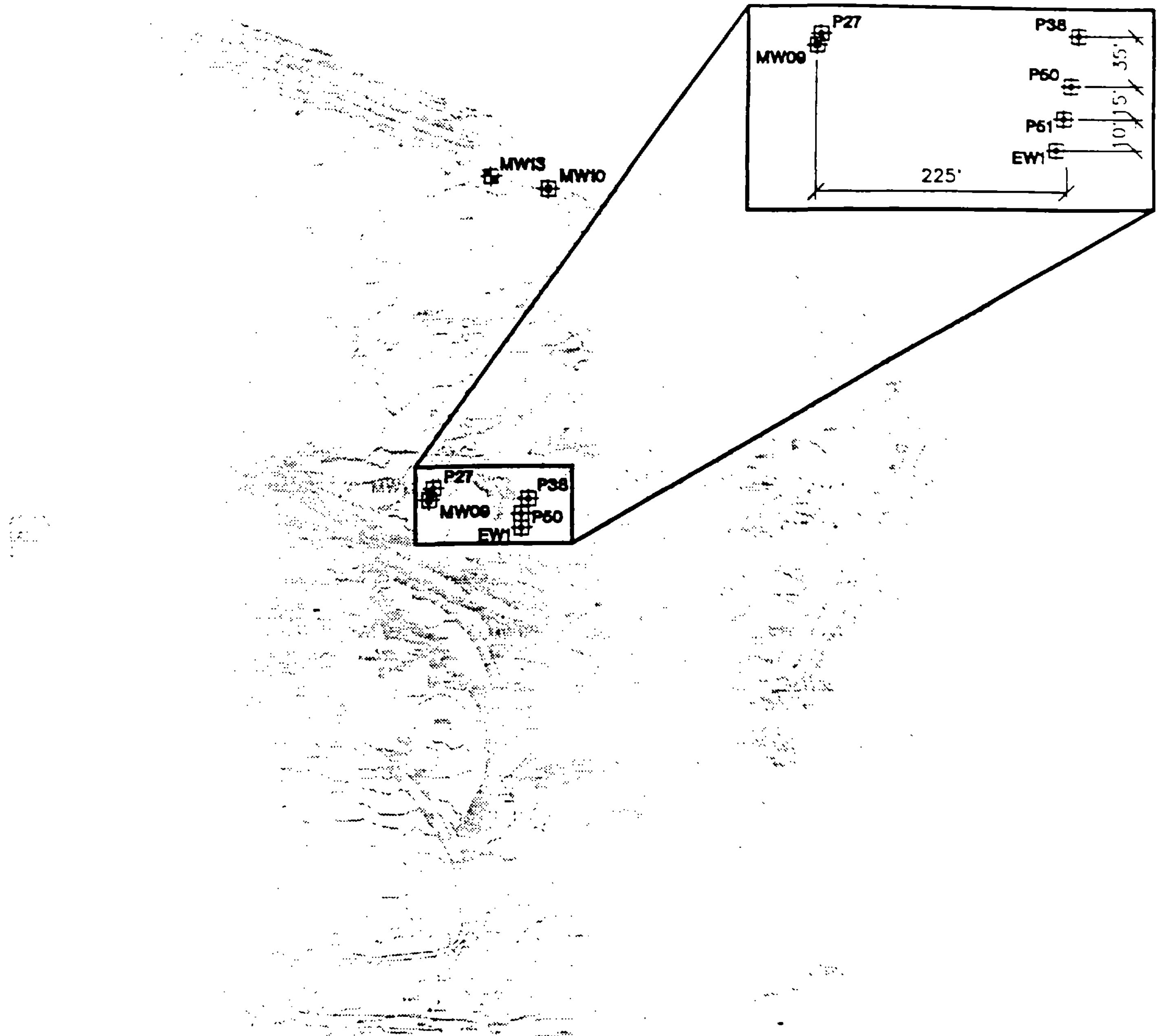
Groundwater quality samples will be collected from the extraction well three or five times during the constant rate test, on a logarithmic time basis to be consistent with the time scale at which the data will be analyzed, (at 0, 10 min, 100 min. 1000 min. 1200 min. and near the end of the test) as indicated on Table A-1. Samples will be analyzed for the parameters listed in Table A-1, which include VOCs, SVOCs, general water chemistry parameters, treatability parameters, and field parameters. Since the data to be generated from the pump test will be used for engineering purposes, DQO Level II protocols will be used for the field analyses and DQO Level III protocols will be used for the laboratory analyses, with the exception that no field duplicates will be sent. The field duplicates are not necessary since the samples will be collected from the same location (i.e., the extraction well effluent) at closely spaced time intervals. Under this scenario, precision and accuracy of a single sample is not critical, especially since the results of consecutive samples can be compared to each other for relative accuracy. The objective of the sampling and analysis is to identify a trend and the expected concentration range after extended pumping. The laboratory methods and detection limits are provided in Table A-2. It is expected that between 15,000 and 30,000 gallons of water will be generated during the pump test. It is anticipated that water extracted during the pump test will be stored on-site in unused ACS tanks until the on-site water treatment plant is constructed and operational.

The water level data will be analyzed to estimate aquifer and well characteristics. It is anticipated that the unconfined aquifer analysis method in the "Aqtesolv" software package will be used to analyze the pump test data. However, test results may require the use of other solutions or correction factors. Montgomery Watson's pump test SOP is included in Appendix C.

1.2 WASTE AREA SAMPLING

Samples of groundwater from the Still Bottoms Area and from the Off-Site Containment Area will be collected using a Geoprobe. The six locations at each area will be selected in the field based upon access restrictions. For each of the two areas, three composite samples will be prepared from the grab samples collected, for a total of six samples submitted for laboratory analysis. The samples will be collected using a low flow pump with disposable tubing.

The samples will not be field filtered (i.e., "Totals" analyses will be performed). Standard Chain-of-Custody, preservation, sample management and holding time procedures and restrictions will be observed. Since the data from the waste area sampling will be used for engineering purposes, DQO Level II protocols will be used for the field analyses and DQO Level III protocols will be used for the laboratory analyses, with the exception that no field duplicates will be sent. The field duplicates would only be of limited value given the high concentrations of organics present in the waste and the resulting interferences in laboratory analyses. The data will be sufficient for its intended purpose without the use of field duplicates. The laboratory methods and detection limits are provided in Table A-2.



LEGEND

UPPER AQUIFER MONITORING WELL LOCATION AND NUMBER

LOWER AQUIFER MONITOIRNG WELL LOCATION AND NUMBER

LEACHATE HEADWELL LOCATION AND NUMBER

PIEZOMETER LOCATION AND NUMBER

APPROXIMATE LOCATION OF GRIFFITH LANDFILL MONITORING WELL

NOTES

1. BASE MAP DEVELOPED FROM AN AERIAL SURVEY MAP OF THE SITE FLOWN ON MARCH 8, 1994 BY GEONEX CHICAGO AERIAL SURVEY, INC. CONTOUR INTERVAL TWO FEET.

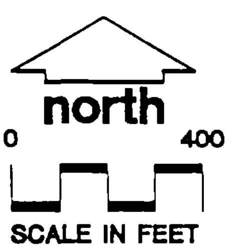


FIGURE A1

Developed By DAP / Drawn By DLF	**PUMP TEST WELL CONFIGURATION MAP**	Drawing Number 4077.0030 A66
Approved By / Date	PUMP TEST TECH–MEMO AMERICAN CHEMICAL SERVICE, INC. NPL SITE GRIFFITH, INDIANA	MONTGOMERY WATSON
Reference		
Revisions		

QUALITY CONTROL
Graphic Standa
Lead Professio
Technical Review
Project Manager
Management Re
Other

This document has been developed for a specific application and may not be used without the written approval of Montgomery Watson.

TABLE A-1

PUMPING TEST
LABORATORY AND FIELD PARAMETERS

	Elapsed Time (Min.)				
	0	10	100	1000	End
Lab Parameters					
VOCs	x	x	x	x	x
SVOCs		x	x		x
Priority Pollutant Metals		x	x		x
Calcium		x	x		x
Magnesium		x	x		x
Potassium		x	x		x
Chloride		x	x		x
Sulfate		x	x		x
Alkalinity		x	x		x
Iron		x	x		x
Manganese		x	x		x
Total Phosphorus		x	x		x
Total Organic Carbon (TOC)		x	x		x
Chemical Oxygen Demand (COD)		x	x		x
Biological Oxygen Demand (BOD)		x	x		x
Hardness		x	x		x
Total Suspended Solids (TSS)	x	x	x	x	x
Total Dissolved Solids (TDS)	x	x	x	x	x
Oil and Grease		x	x		x
Total Kjeldahl Nitrogen (TKN)		x	x		x
Field Parameters					
pH	x	x	x	x	x
Specific Conductance	x	x	x	x	x
Temperature	x	x	x	x	x
Dissolved Oxygen	x	x	x	x	x

TABLE A-2

SUMMARY OF PARAMETER ANALYTICAL METHODS AND REPORTING LIMITS
American Chemical Services Inc.
Griffith, Indiana

Parameter	Method		RL	Units
Volatile Organic Compounds				
1,1,1-Trichloroethane	SW-846	8010/8020	1	ug/L
1,1,2,2-Tetrachloroethane	SW-846	8010/8020	1	ug/L
1,1,2-Trichloroethane	SW-846	8010/8020	1	ug/L
1,1-Dichloroethane	SW-846	8010/8020	1	ug/L
1,1-Dichloroethene	SW-846	8010/8020	1	ug/L
1,2-Dichlorobenzene	SW-846	8010/8020	1	ug/L
1,2-Dichloroethane	SW-846	8010/8020	1	ug/L
1,2-Dichloroethene, cis-	SW-846	8010/8020	1	ug/L
1,2-Dichloroethene, trans-	SW-846	8010/8020	1	ug/L
1,2-Dichloropropane	SW-846	8010/8020	1	ug/L
1,3-Dichlorobenzene	SW-846	8010/8020	1	ug/L
1,3-Dichloropropene, cis-	SW-846	8010/8020	1	ug/L
1,3-Dichloropropene, trans-	SW-846	8010/8020	1	ug/L
1,4-Dichlorobenzene	SW-846	8010/8020	1	ug/L
2-Chloroethyl vinyl ether	SW-846	8010/8020	10	ug/L
Acrolein	SW-846	8010/8020	100	ug/L
Acrylonitrile	SW-846	8010/8020	100	ug/L
Benzene	SW-846	8010/8020	1	ug/L
Bromodichloromethane	SW-846	8010/8020	1	ug/L
Bromoform	SW-846	8010/8020	1	ug/L
Bromomethane	SW-846	8010/8020	2	ug/L
Carbon tetrachloride	SW-846	8010/8020	1	ug/L
Chlorobenzene	SW-846	8010/8020	1	ug/L
Chlorodibromomethane	SW-846	8010/8020	1	ug/L
Chloroethane	SW-846	8010/8020	2	ug/L
Chloroform	SW-846	8010/8020	1	ug/L
Chloromethane	SW-846	8010/8020	2	ug/L
Ethylbenzene	SW-846	8010/8020	1	ug/L
Methylene chloride	SW-846	8010/8020	3	ug/L
Tetrachloroethene	SW-846	8010/8020	1	ug/L

TABLE A-2

SUMMARY OF PARAMETER ANALYTICAL METHODS AND REPORTING LIMITS
American Chemical Services Inc.
Griffith, Indiana

Parameter	Method		RL	Units
Semivolatile Organic Compounds				
Toluene	SW-846	8010/8020	1	ug/L
Trichloroethene	SW-846	8010/8020	1	ug/L
Trichlorofluoromethane	SW-846	8010/8020	1	ug/L
Vinyl chloride	SW-846	8010/8020	1	ug/L
Xylene, m+p-	SW-846	8010/8020	2	ug/L
Xylene, o-	SW-846	8010/8020	1	ug/L
1,2,4-Trichlorobenzene	SW-846	8270	10	ug/L
1,2-Dichlorobenzene	SW-846	8270	10	ug/L
1,2-Diphenylhydrazine	SW-846	8270	10	ug/L
1,3-Dichlorobenzene	SW-846	8270	10	ug/L
1,4-Dichlorobenzene	SW-846	8270	10	ug/L
2,4,6-Trichlorophenol	SW-846	8270	10	ug/L
2,4-Dichlorophenol	SW-846	8270	10	ug/L
2,4-Dimethylphenol	SW-846	8270	10	ug/L
2,4-Dinitrophenol	SW-846	8270	50	ug/L
2,4-Dinitrotoluene	SW-846	8270	10	ug/L
2,6-Dinitrotoluene	SW-846	8270	10	ug/L
2-Chloronaphthalene	SW-846	8270	10	ug/L
2-Chlorophenol	SW-846	8270	10	ug/L
2-Nitrophenol	SW-846	8270	10	ug/L
3,3-Dichlorobenzidine	SW-846	8270	20	ug/L
4,6-Dinitro-2-methylphenol	SW-846	8270	50	ug/L
4-Bromophenyl phenyl ether	SW-846	8270	10	ug/L
4-Chloro-3-methylphenol	SW-846	8270	20	ug/L
4-Chlorophenyl phenyl ether	SW-846	8270	10	ug/L
4-Nitrophenol	SW-846	8270	50	ug/L
Acenaphthene	SW-846	8270	10	ug/L
Acenaphthylene	SW-846	8270	10	ug/L
Anthracene	SW-846	8270	10	ug/L
Benzidine	SW-846	8270	50	ug/L
Benzo(a)anthracene	SW-846	8270	10	ug/L
Benzo(a)pyrene	SW-846	8270	10	ug/L
Benzo(b)fluoranthene	SW-846	8270	10	ug/L
Benzo(g,h,i)perylene	SW-846	8270	10	ug/L

TABLE A-2

SUMMARY OF PARAMETER ANALYTICAL METHODS AND REPORTING LIMITS
American Chemical Services Inc.
Griffith, Indiana

Parameter	Method		RL	Units
Semivolatile Organic Compounds (continued)				
Benzo(k)fluoranthene	SW-846	8270	10	ug/L
Bis(2-Chloroethyl)ether	SW-846	8270	10	ug/L
Bis(2-chloroethoxy)methane	SW-846	8270	10	ug/L
Bis(2-chloroisopropyl)ether	SW-846	8270	10	ug/L
Bis(2-ethylhexyl)phthalate	SW-846	8270	10	ug/L
Butylbenzylphthalate	SW-846	8270	10	ug/L
Chrysene	SW-846	8270	10	ug/L
Di-n-butylphthalate	SW-846	8270	10	ug/L
Di-*n*-octyl phthalate	SW-846	8270	10	ug/L
Dibenzo(a,h)anthracene	SW-846	8270	10	ug/L
Diethyl phthalate	SW-846	8270	10	ug/L
Dimethyl phthalate	SW-846	8270	10	ug/L
Fluoranthene	SW-846	8270	10	ug/L
Fluorene	SW-846	8270	10	ug/L
Hexachlorobenzene	SW-846	8270	10	ug/L
Hexachlorobutadiene	SW-846	8270	10	ug/L
Hexachlorocyclopentadiene	SW-846	8270	20	ug/L
Hexachloroethane	SW-846	8270	10	ug/L
Indeno(1,2,3-cd)pyrene	SW-846	8270	10	ug/L
Isophorone	SW-846	8270	10	ug/L
Naphthalene	SW-846	8270	10	ug/L
Nitrobenzene	SW-846	8270	10	ug/L
Pentachlorophenol	SW-846	8270	50	ug/L
Phenanthrene	SW-846	8270	10	ug/L
Phenol	SW-846	8270	10	ug/L
Pyrene	SW-846	8270	10	ug/L
n-Nitroso-di-n-propylamine	SW-846	8270	10	ug/L
n-Nitrosodimethylamine	SW-846	8270	50	ug/L
n-Nitrosodiphenylamine	SW-846	8270	10	ug/L
METALS				
Antimony	EPA-600	204.2	0.002	mg/L
Arsenic	EPA-600	206.2	0.001	mg/L
Beryllium	EPA-600	200.7	0.005	mg/L

TABLE A-2

SUMMARY OF PARAMETER ANALYTICAL METHODS AND REPORTING LIMITS
American Chemical Services Inc.
Griffith, Indiana

Parameter	Method		RL	Units
METALS (continued)				
Cadmium	EPA-600	200.7	0.005	mg/L
Calcium	EPA-600	200.7	1.00	mg/L
Chromium	EPA-600	200.7	0.01	mg/L
Copper	EPA-600	200.7	0.01	mg/L
Iron	EPA-600	200.7	0.02	mg/L
Lead	EPA-600	239.2	0.0015	mg/L
Magnesium	EPA-600	200.7	1.00	mg/L
Mercury	EPA-600	245.1	0.0002	mg/L
Nickel	EPA-600	200.7	0.02	mg/L
Potassium	EPA-600	322B	0.10	mg/L
Selenium	EPA-600	270.2	0.002	mg/L
Silver	EPA-600	200.7	0.01	mg/L
Sodium	EPA-600	200.7	2.00	mg/L
Thallium	EPA-600	279.2	0.001	mg/L
Zinc	EPA-600	200.7	0.01	mg/L
INDICATORS				
Alkalinity	EPA-600	310.1/310.2	10	mg/L
Biological Oxygen Demand	Std Methods	5210, 4500-0	1	mg/L
Chemical Oxygen Demand	EPA-600	410.4	20	mg/L
Chloride	EPA-600	325.2	2	mg/L
Hardness	EPA-600	130.1	10	mg/L
Nitrogen, total Kjeldahl	EPA-600	351.3	0.10	mg/L
Oil & Grease	EPA-600	413.1	1	mg/L
Phosphorus, total	EPA-600	365.1	0.02	mg/L
Solids, Total Dissolved	EPA-600	160.1	20	mg/L
Solids, Total Suspended	EPA-600	160.2	2	mg/L
Sulfate	EPA-600	375.2	10	mg/L
Total Organic Carbon	EPA-600	415.1	0.25	mg/L

This table presents the parameter name, method reference, and reporting limits used to analyze pump test and leachate samples collected from the ACS site during March and April, 1995.

Appendix B

MONTGOMERY WATSON

APPENDIX B

SOIL BORING/WELL INSTALLATION STANDARD OPERATING PROCEDURES

Section: Subsurface Exploration and Sampling	Section Number 103	Date of Issue April 1993	Reviewed By G. Prior
Subject: Hollow Stem Augering	Page 1 of 15	Date Revised \	Authorized By

Scope and Application: This method is applicable to drilling unconsolidated or loosely consolidated formations for well installation and soil sampling up to 70 ft deep; and for drilling garbage for well installation.

Method: Appropriately sized hollow stem augers.

Reference: ASTM D1586-84, ASTM D158-83, Unified Soil Classification System
For Wisconsin: - Chapter NR 141 Wisconsin Administrative Code.

I. PRE-FIELD CHECKLIST

A. Health and safety plan with related instruments

B. Underground utility check: 5 to 7 day advance notice

C. Off-Site access agreements completed

D. Sampling plan detailing sample types, sample intervals and sampling objectives

E. Field boring log forms: Warzyn Standard or Client Specific (i.e. Waste Management Inc. or BFI form if drilling for them)

F. Daily Drilling Summary (see Drilling RFQ Preparation SOP)

G. Unified Soil Classification System Summary (see Boring Log Preparation SOP)

H. Warzyn's general notes on Log of Test Boring

I. Munsell soil color chart (generally optional - required for Wisconsin solid waste projects)

J. Decon solutions, brushes, buckets, etc.

K. Soil jars (laboratory grade and/or driller's grade)

L. Jar-labels, marking pens (do not use water soluble ink)

M. Driller contacted and informed:
1. Health and safety plan
2. Utility check
3. Sampling plan
4. Water source: clean, high-capacity source
5. Disposal of drill cuttings and fluids
6. Decon pad construction - if necessary
7. Equipment/material storage area

N. 100' tape measure with weighted sounding device

O. Pocket penetrometer

P. Soil knife/spatula

Q. Well/Borehole Abandonment Forms

R. Monitoring Well Construction Forms

S. Well Development Forms

II. FIELD CHECKLIST

A. Check for unmarked or uncleared utilities: drive around, walk around

B. Check for overhead wires

C. Drill rig access

Section: Subsurface Exploration and Sampling	Section Number 103	Date of Issue April 1993	Reviewed By G. Prior
Subject: Hollow Stem Augering	Page 3 of 15	Date Revised \	Authorized By

D. Borehole location correctly staked and labelled

E. Steam clean augers, drill rods, samplers, hand tools, drill rig

F. Count number of augers - to determine number used during drilling and, therefore, total depth drilled

G. Count number of drill rods - to determine number used during drilling and, therefore, total depth drilled

H. Measure length of split spoon sampler/Shelby tubes

I. Measure length of lead auger

J. Confirm the correct well construction or borehole abandonment materials are present

K. Health and safety briefing

L. Soil jars prepared

M. Drill and sample the deepest hole at a well nest first, unless directed otherwise by a Work Plan

III. HOLLOW STEM AUGERING FOR WELL INSTALLATION AND SPLIT SPOON SAMPLING

A. Must have appropriately sized augers: minimum 2¼ in. I.D. to maximum 6¼ in. I.D. for split spoon sampling; minimum inside diameter of 4¼ in. greater than the nominal diameter of the well casing.

B. Must use center bit when performing split spoon sample collection for any chemical analysis. This isolates the sample interval and prevents cross contamination.

C. Collect split spoon samples at 2½ ft intervals in the top 10 ft, then at 5 ft intervals thereafter, unless specified otherwise in Work Plan. Representative soil samples should be place in jars and retained for later review and/or analysis, unless indicated otherwise in the Work Plan. At Wisconsin LUST sites, the entire boring must be sampled at 2 1/2 in. intervals. Collect split spoon samples at each change in strata. Shelby tube samples may need to be collected in clay soils. Boreholes with adjacent previously sampled piezometers may be "blind drilled" without any soil sampling.

D. Split spoon sampling - standard penetration test (SPT).

1. Inspect split spoon.

   a. Measure length of spoon from tip to shoe.

   b. Spoon tip must not be gouged, bent, or excessively worn.

   c. Spoon shoe must have a check valve; the check valve should be free of soil and be able to seal.

   d. Spoon tip may contain a spring sample catcher which is clean and in good working order.

   e. Split spoon should meet the construction specifications shown in Figure 1. If a larger split spoon is used, its diameter will be noted.

   f. Split spoon should be clean: initially steam cleaned; between samples use TSP/Liquinox wash and triple rinse with clean water, if the split spoon samples are for chemical analysis.

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2. Check sampling hammer.

   a. 140 lb hammer which free falls for 30 in.; 140 lb x 2.5 ft = 350 ft-lb of torque

   b. If used with a cathead, no more than 2¼ rope turns on cathead; cathead should be free of rust, grease and oil, and should be 6 to 10 in. in diameter

   c. If using an automatic trip hammer, check the throw length and hammer fall height (30 in. free fall onto anvil)

   d. If a larger hammer is used, note the sample hammer torque

3. Check drill depth: drill depth (Dd) = length of drill string (Ld) minus stick up (SU); Dd = Ld - SU. See Figure 2

4. Driller will insert split spoon into augers and lower to the bottom in a controlled manner; do not allow the split spoon to freely drop to the bottom.

5. Check split spoon sampler depth: split spoon depth (Dss) equals length of sampler string (Ls) minus stick up (SU); Dss = Ls - SU. See Figure 3

6. The depth of the split spoon must be within 4 in. of the drilling depth before commencing the Standard Penetration Test. If the drill depth minus the split spoon depth is greater than 4 in., then do not initiate the test (Dd - Dss >4 in. → no test); the driller must clean out the borehole. Do not allow the driller to jet water thru the split spoon to advance it to the drill depth.

7. If Dd - Dss <4 in. the test can start.

   a. The driller should measure and mark the drill rods in 6 in. increments; three 6 in. increments are normally marked, but four or more 6 in. increments may be marked should extra sample volume be desired.

   b. Driller places steel anvil onto drill rods and automatic trip hammer or places safety hammer onto drill rods. The hammer force should strike the drill rods and sampler with a metal to metal contact.

   c. Raise the sample hammer and allow it to free fall 30 in. to strike the drill rods.

   d. The driller will count the number of hammer blows required to advance the sampler through each 6 in. interval.

   e. Stop the test if the sampler fails to advance; split spoon refusal is 100 blows for 6 in. or less.

   f. Drive the sampler for 18 in. or more; record the blow counts for each 6 in. interval.

8. Pull the split spoon out of the borehole and remove it from the drill rods.

E. Handling the split spoon sample.

   1. Carefully open the split spoon or have the driller do it; do not disturb the sample any more than necessary; do not slam the split spoon; use a pipe vise or pipe wrench to compress the split spoon perpendicular to its seams; unscrew the shoe first, then the tip; use a large screw driver to pry apart the split spoon.

2. Recognize and discard any soil plug, sluff or blow-in at the upper portion of the sample.

3. Measure and record the sample recovery length (inches).

4. Use a clean spatula to place soil from the lower portion of the sample into a pre-labelled soil jar. If PID or FID field screening is required, grab this sample first (see PID/FID Headspace Screening of Soil Samples SOP). If there is a major change in lithology, samples should be subdivided and labeled as separate subsamples of a given split spoon. For example, if sample 10-SS encounters three changes in lithology, the bottom 6 in. is labeled 10-SS, the middle 6 in. is labeled 10-X, and the top 6 in. is labeled 10-XX.

5. If sampling for chemical parameters fill VOC jars first (with no headspace) then other jars before filling geotechnical jar. Wipe soil from threads of the jar samples and securely tighten the jar cap.

6. Perform pocket penetrometer test. This test must be performed when cohesive soils are encountered.

   a. For cohesive soils only

   b. 'Zero' the pocket pen

   c. Hold the pocket pen at a right angle to the soil sample surface and steadily push the piston into the soil up to the calibration groove. Read the unconfined compressive strength in tons/sq. ft. Take several readings, discard the high and low readings; record an average reading.

7. Perform Munsell soil color test (if required).
   a. Record soil hue and chroma
   b. Record soil color name
   c. Example: Brown (7.5 YR 5/2)

8. Describe the soil sample - see Boring and Test Pit Log SOP

   a. Consistency: for cohesive soils only; determined from pocket pen readings and Warzyn's general notes; or

   b. Density: for non cohesive soils only; determined from the blow counts (N value) and Warzyn's general notes.

   c. Color: use munsell, or common language; avoid bizarre names such as 'rusty brown', 'chocolate', 'lemon yellow'; keep it simple.

   d. Major soil type with modifier: such as silty fine <u>sand</u>, or fine to coarse sandy <u>lean clay</u>.

   e. Minor soil proportions: trace, little, some according to Warzyn's general notes; such as fine sand, little silt, trace fine gravel; lean clay, little fine sand, trace fine gravel.

   f. Unified Soil Classification System: assign a USCS group symbol to the soil description; the USCS group symbol should be consistent with major and minor soil description.

   g. Describe soil moisture: use 'W' for wet (free water readily apparent), or 'M' for moist (no visible free water but soil particles adhere). Avoid using 'D' for 'damp' or 'dry' and S 'saturated'.

   h. The soil description should apply to the soil placed into the soil jar. Further describe the split spoon sample by noting other features in the split spoon. For example: If the split spoon contains alternating layers of fine sand, silt, and clay ranging from 6 in. to 1/4 in. thick and the bottom portion of the split spoon is a 6 in. clay seam, place the clay seam into the jar and describe it. But also describe the remaining portion of the soil profile in the spoon. Stiff, brown silty clay (CL-ML) moist, with alternating horizontal layers of wet fine sand (SP), silt (ML), and silty clay (ML-CL), 6 to 1/4 in. thick, glacial lacustrine. Do not describe only the clay portion and omit the horizontal wet sand and silt seams. Do not stuff the sand and silt seams into a jar and describe the silty clay. The soil description and USCS symbol should represent the soil in the jar, but also describe other features in the spoon. The boring log should accurately reflect the soil observed, not just the soil submitted for analysis.

j. Also describe soil structure (mottled, massive, laminated, cross bedded, blocky, etc.), predominant grain shape (angular to rounded), geologic origin if apparent (glacial, aeolian, residual, etc.), and presence of silt or sand seams in clay soils or clay seams in sand soils.

k. Soil samples should be retained in jars for later review and/or testing, unless indicated otherwise in the work plan.

8. Clean and decontaminate the split spoon

   a. Scrape off soil and pre-wash; check for freely working ball check valve in shoe; replace spring sample catcher in tip if necessary; check condition of tip and replace if worn

   b. TSP/Liquinox wash with stiff bristled brush

   c. Triple rinse with clean water

9. Assemble split spoon.

F. Shelby tube sampling.

1. Used for recovering relatively undisturbed samples of cohesive soils; also applicable to recovering larger sample volumes than a regular split spoon.

2. Inspect Shelby tube.

   a. Sharp end

   b. Tube straight with no dents, no extruding seams

   c. Rust free

   d. Steam cleaned (if environmental boring - Shelby tubes are often coated with oil to prevent rust)

3. Inspect Shelby tube head.
   a. Check ball valve clean and in good working order
   b. Allen screws clean or spring loaded head functioning

4. Measure length of assembled tube and head.

5. Check drill depth: drill depth (Dd) = length of drill string (Ld) minus stick up (SU); Dd = Ld - SU. (see Figure 1)

6. Insert Shelby tube into the augers and lower it to the bottom in a controlled manner; do not allow the tube to free fall to the bottom.

7. Check and record Shelby tube depth: tube depth (Dst) equals length of sampler string (Ls) minus stick up (SU); Dst = Ls - SU.

8. The Shelby tube must not be pushed through the soil plug in the augers. *If Dd - Dst >0, then the driller should clean out the soil plug before pushing the Shelby tube.*

9. Use the rig hydraulics to advance the tube sampler without rotation using a relatively rapid continuous motion. The length of advance should be no greater than the functional inside length of the tube.

Advance the tube until it is full or until it is refused. Record the length of advance.

10. If the formation is too hard for push type insertion the tube may be advanced using a sample hammer. However, this may risk losing the Shelby tube in the augers or borehole. If driving methods are used, record the sample hammer weight and fall length. Other methods for obtaining tube samples in hard formations are the Denison sampler and Pitcher sampler.

11. Allow several minutes before retracting the tube so the soil can develop a bond with the tube.

12. The tube may be rotated to shear bottom of the sample.

13. Pull the Shelby tube out of the augers; immediately place a cap onto the tube bottom; remove the tube from the tube head.

G. Shelby tube sample handling.

1. Remove disturbed material from the upper end of the tube: hold the tube upside down and gently tap it vertically on a hard surface until the loose material slides out

2. Measure and record the length of material in the tube

3. Use a soil spatula to remove 1 in. of material from the bottom of the tube; use this for soil description (see E, #7)

4. Perform pocket penetrometer test (see E, #5)

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5. Seal the tube ends

   a. If the tube end is crimped, cut it off using a hack saw

   b. Use end padding in end voids to prevent drainage or movement of the soil within the tube; use loosely wadded newspaper, or packing material consistent with chemical or physical analyses

   c. Cap over both ends of the tube with Shelby tube caps

   d. Wash the exterior of the tube to remove soil and contaminants

   e. Use duct tape or electrical tape to seal over the cap ends and tube holes

   f. Do not use wax to seal the tube

6. Label the sample

   a. Top end cap: job #, boring #, sample #, depth, date

   b. Side of tube: job #, boring #, sample #, depth; indicate 'This End Up' at several places on the tube; indicate the soil level in the tube with a solid ring mark

7. Shelby tube samples are very fragile; store and transport them carefully

   a. Store upright; don't let them roll around in the van

   b. Do not allow them to freeze; store away from heaters

   c. Shipping is a real problem; sometimes it is necessary to cut the tube into smaller sub samples for shipment. Clearly label and document all subsamples cut for shipping

IV. DOCUMENTATION

A. Field boring log - see examples in Boring and Test Pit Log SOP and attachments; choose only from these options for field boring logs. Typed final boring logs are not part of this SOP.

1. Warzyn's Field Boring Log

2. Wisconsin DNR Soil Boring Log - required in Wisconsin

3. Waste Management's Field Log - Soil Borehole
   a. Required on Waste Management projects
   b. In Wisconsin, must also submit Wisconsin's DNR soil boring log

4. Other states or clients may require specific field boring logs

B. Daily Drilling Summary and Daily Project Summary - see examples in Drilling RFQ Preparation ____.

1. Used to track drill rig utilization and materials' use

2. Excellent resource to check billing and identify pay items and out of scope activities

3. Detail the drill crew's work in 1/4 hr intervals and explain in 'remarks'

C. Monitoring Well Construction Summary - see well installation SOP.

D. Borehole Abandonment form - see Attachment ____.

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V. BOREHOLE DISPOSITION

A. Cover and protect incomplete boreholes
   1. Keep children or animals from falling in
   2. Keep vandals out

B. Each borehole log should have an associated monitoring well construction summary, or abandonment report

VI. BOREHOLE ABANDONMENT

A. The purpose of borehole abandonment is to completely fill the borehole so it will not act as a vertical conduit for contaminant flow, and to prevent people or livestock from falling or stepping into the hole. Document borehole abandonment using Warzyn's Well/Borehole Abandonment Form.

B. Boreholes less than 10 ft deep which do not intersect the water table may be backfilled with uncontaminated drill cuttings. If the drill cuttings are contaminated they should be contained, and the borehole should be backfilled with materials less permeable than the formation.

C. Use bentonite granules in borings less than 25 ft deep provided there is no standing water in the borehole.

D. Bentonite chips or pellets can be used in borings less than 50 ft deep provided there is less than 30 ft of standing water in the borehole.

E. For other applications, use bentonite-cement grout pumped through a tremie pipe set to the borehole bottom in any borehole. Use this mix recipe: 6 1/2 gal of water plus 94 lb Portland Type 1 cement plus 3 to 5 lb bentonite powder to yield approximately 1 1/2 times the water volume used.

F. Record the type and volume of sealant(s) used and report the mix recipe and method placement.

G. Check for sealant settlement after 24 hr and top it off with more sealant.

H. Stake the borehole location. Before leaving the site locate the boring relative to two fixed site features (not other borings or wells) so the boring can be readily located on the site map.

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INTRODUCTION

This standard operating procedure (SOP) is for soil and rock classification, preparation of field boring and test pit logs, review of logs by professionals in our office, and preparing final logs to be included in Warzyn project reports. It is important to remember when preparing logs that the level of detail should be sufficient so that they will be adequately useful to any of our technical professionals, including hydrogeologists and geotechnical engineers. This means, for example, that soils should be classified according to the Unified Soil Classification System (USCS) based on visual observation supplemented by the results of laboratory soil index tests (such as grain-size analysis, Atterberg limits, natural moisture content, and organic content by loss-on-ignition when organic soil is suspected). In addition to standard procedures in this document, several states have specific requirements for specific purposes (e.g., Wisconsin Administrative Code, Chapters NR 141 and NR 500). These rules or guidelines should be carefully reviewed before proceeding with a drilling program and logs should be prepared in accordance with code requirements. Every borehole or test pit should have a field log prepared, regardless of whether a final log will be included in the report.

REVIEW PROCEDURE FOR QUALITY CONTROL

All field logs require review editing before they are finaled for submittal with project reports. Field logs are usually prepared by Warzyn field staff supervising the drilling or test pit excavation, or on rare occasions directly by the subcontracted drilling crew. Experienced professional staff, usually a geologist, hydrogeologist, or geotechnical engineer, need to review the field logs. The soil and/or rock samples should also be reviewed by an experienced professional when the field staff is not very experienced in sample classification or if logs are prepared by the drilling crew. When feasible, it is best to review the field logs prior to data entry into gINT (Geotechnical Integrator, a geologic/geotechnical data base; see gINT SOP for use of the gINT program). Soil descriptions based on visual observations should be edited so that they are consistent with the results of the laboratory soil tests. Prior to submittal with project reports, all data entry on final logs should be thoroughly checked against original data. This includes checking of stratification line depths, geologic symbols, and sample depth intervals. Both the initials of the person preparing the field logs and the person reviewing/editing the logs should be on the final logs.

SOIL CLASSIFICATION AND DESCRIPTIONS

Where feasible, the following items should be included for all soil descriptions on logs:

- consistency for cohesive soils and relative density for granular soils
- color and any mottling
- major soil proportion with the USCS symbols
- minor soil proportion
- grain angularity
- scattered/numerous constituents (such as cobbles, boulders, lenses)
- any unusual odor
- genetic descriptions, such as till or loess, if known

Check applicable state codes for specific information that may be required, such as use of the Munsell color chart.

Consistency

The consistency of a clay or cohesive silt is based on its unconfined compressive strength (Q_u or q_u value). Unconfined compressive strength can be estimated using a pocket penetrometer in the field, or from unconfined compression or unconsolidated undrained (UU) triaxial compression testing in the laboratory. On the log, the unconfined strength value is reported in ton/sq ft units, shown in parentheses to the nearest 0.1 ton/sq ft from pocket penetrometer readings (q_a), and shown without parentheses to the nearest 0.01 ton/sq ft from laboratory testing. The consistency description to be used based on these values is shown below:

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Consistency	Unconfined Compressive Strength (ton/sq ft)	Approx. N-Value
Very Soft	Less than 0.25	0 to 2
Soft	0.25 to 0.50	2 to 4
Medium Stiff	0.50 to 1.00	4 to 8
Stiff	1.00 to 2.00	8 to 16
Very Stiff	2.00 to 4.00	16 to 32
Hard	More than 4.00	More than 32

If a pocket penetrometer reading cannot be obtained for a cohesive soil sample but SPT (Standard Penetration Test, ASTM D1586) blow counts are available, the consistency can be estimated based on the range of N-values shown above.

Relative Density

The relative density of a sand, gravel or granular silt is estimated based on the SPT N-value in blows/ft (blow counts). The relative density description to be used based on the range of blow counts is shown below:

Relative Density	SPT N-Value (blows/ft)
Very Loose	0 to 4
Loose	4 to 10
Medium Dense	10 to 30
Dense	30 to 50
Very Dense	Over 50

Color

Soil or rock color should always be included with the description on the log. Modifiers to the color description should also be included where appropriate, such as light, dark or mottled. Some agencies, such as the Wisconsin Department of Natural Resources, also require Munsell chart color notation.

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Major Soil Proportion

The major soil proportion in the description should be shown in all capital letters on the logs so that it stands out. Modifiers with only the first letter capitalized should also be used where appropriate. Appropriate modifiers vary depending on the soil type as indicated below:

Clay--silty, lean, fat, organic, sandy, gravelly
Silt-- organic, sandy, gravelly, elastic
Sand--fine, medium, coarse, silty, clayey
Gravel--fine, coarse, silty, clayey
Peat--sedimentary, fibrous, or woody

Clay should always be described as silty, lean, or fat depending on its known or estimated Atterberg limits values. Silt may be elastic depending on the Atterberg limits values. Clay or silt are "organic" if the known or estimated organic content is 4% or greater based on loss-on-ignition (LI) tests. Clay and silt are sandy and gravelly if the sand or gravel content, respectively, is 35% or greater but less than 50%.

When sand or gravel is the major soil proportion, it should always be described as fine, medium, and/or coarse (e.g., Fine to Medium, Fine to Coarse, or Medium to Coarse if there are a range of particle sizes). If a sand has a gravel content of 35% or greater or if a gravel has a sand content of 35% or greater, the major soil proportion in either case should be described as SAND & GRAVEL. If 35% or more (but less than 50%) of a sand or gravel soil consists of silt and/or clay, a modifier of Silty or Clayey should be used. Whether the soil is silty or clayey depends on the known or estimated Atterberg limits values.

Peat is organic soil with an organic content of more than 12% as measured by the LI test. If the organic content is between 12 and 50%, then it is described as Sedimentary PEAT. If the organic content is more than 50%, then it is described as Fibrous or Woody PEAT.

Guidelines for field classification of soil based on visual observations are contained in Table 1 and Appendix A.

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Minor Soil Proportion

Soil descriptions usually mention the minor soil proportions of silt, clay, sand and/or gravel that are often present. Modifiers to use with the minor soil proportions are the following:

Trace--5% or less
Little--5 to 12%
Some--12 to 35%

The minor soil proportion descriptions are limited to those for sand or gravel when the major proportion is clay; clay, sand or gravel when the major proportion is silt; silt, clay or sand when the major proportion is gravel; and silt, clay or gravel when the major proportion is sand.

USCS Symbols

The soil description should be followed by the USCS symbols shown in parentheses (Table 2 and Appendix B). Some examples are:

Loose, Brown Fine SAND, Little Silt (SP-SM)
Dense, Brown Fine to Coarse Sand and GRAVEL, Some Silt (GM)
Stiff, Gray Silty CLAY, Little Fine Sand (CL-ML)

For visual classification of sands and gravel with less than 12% silt and/or clay content, the USCS symbols of SP, SP-SC, SP-SM, GP, GP-GC, or GP-GM are used as appropriate rather than SW, SW-SC, SW-SM, GW, GW-GC, or GW-GM. P signifies poorly graded and W means well graded. Few natural soils are well graded. A soil should not be classified as well graded unless it is confirmed by grain size analysis testing. A well-graded sand (SW, SW-SC, or SW-SM) has a coefficient of curvature (C_c) value between 1 and 3 and a coefficient of uniformity (C_u) value of 6 or more. A well-graded gravel (GW, GW-GC, or GW-GM) has a C_c value between 1 and 3 and C_u value of 4 or more. C_c and C_u values are obtained from laboratory grain-size analysis (Appendix C).

Grain Angularity

Describe the predominant angularity of grains larger than medium sand as angular, subangular, rounded or subrounded. A range of angularity may be stated such as rounded to subrounded.

Scattered/Numerous Constituents

Other constituents in the soil that are observed should also be noted on the logs. This includes the presence of cobbles, boulders, and lenses or layers of discontinuous soil that are not thick enough to be considered a separate major soil unit. Based on their dimensions, these constituents are described as follows:

Boulders--larger than 12 in. in diameter
Cobbles--3 to 12 in. in diameter
Layers--more than 1 in. thick
Lenses--1 in. or less in thickness

Modifiers should also be used when describing these constituents based on their frequency of occurrence. For example, use "Scattered" to mean "a few" and "Numerous" to mean "many". Avoid use of words such as "occasional" which have temporal rather than spatial significance.

Topsoil

Where feasible, topsoil should be described based on its major soil proportion using the modifiers noted above, and then adding Topsoil to the description. Use the topsoil material graphic symbol on the log and geologic cross sections (Appendix G). Usually for thin surficial topsoil layers, no attempt is made to describe its consistency or relative density. For example:

Black Organic SILT Topsoil, Trace Sand (OL) Scattered Roots

When fill overlies a topsoil layer, it should be noted as Possible Buried Topsoil or Probable Buried Topsoil, depending on the degree of confidence that the layer is buried topsoil. When buried topsoil is encountered, an attempt should be made to describe its consistency or relative density if the N-value or pocket penetrometer reading is available, particularly if the layer is more than 6 in. thick. For example:

Stiff, Black Organic SILT (OL) Scattered Roots (Probable Buried Topsoil)

Fill

When encountered, fill should be noted in all capital letters and described as noted above for the soil constituents that are present. Sometimes the USCS symbols are omitted and no attempt is made to describe the consistency or relative density of the fill; however, the USCS symbols should be included when feasible. It should be remembered that many times fill is not placed in a controlled manner and, while one location may appear to be dense, another location nearby may be very loose. In other words, the N-values or pocket penetrometer readings in fill can be deceptive. Also, fill is often very heterogeneous material (i.e., not a uniform material type throughout the fill zone). If fill is suspected but not certain, the soil unit can be described as Possible Fill or Probable Fill depending on the likelihood that it is fill. For example:

> Medium Dense, Brown Silty Fine SAND, Trace Gravel (SM) Angular Gravel (Possible Fill)

Nonsoil constituents observed in the fill should also be described, such as scattered or numerous pieces of wood, concrete or brick; or trace, little or some topsoil, cinders or roots. For example:

> FILL: Brown Fine to Coarse Sand and Gravel, Some Silt and Cinders, Trace Topsoil, Scattered Pieces of Wood and Concrete

Any unusual odors should also be noted.

ROCK CLASSIFICATION AND DESCRIPTIONS

It is important to accurately and completely describe rock cores at the drill site because often the field geologist or engineer is the only person to see the cores. Rock cores should be color photographed for a permanent record, to be sent to the file or included with the report. As a minimum, the rock core descriptions should include color, weathering, structure, and rock type. The typical components of a rock description are listed in Table 3. Rock classification is discussed in Appendix D.

If the presence of bedrock is suspected based on rock chips collected from the split spoon or drill cuttings, and no coring is performed, then the layer should be noted as Possible Bedrock or Probable Bedrock depending on the degree of certainty. For example:

Light Brown DOLOMITE (Probable Bedrock)

A specific description of each discrete section of the core is required. Run number, run length, run depth interval, percent recovery, percent RQD (rock quality designator), and fractures per foot need to be recorded on the log. Fluid loss (depth and approximate volume) and qualitative degree of drilling difficulty should be noted where appropriate. An example rock description for a run interval on a field log is as follows:

Run #1: 184.2 to 194.2; 9.6' recovery of gray, very slightly weathered, massive, vuggy, micritic DOLOMITE; scattered unidentified fossils; fractures are horizontal and stained brown; vugs range from 1/4 in. to 3/4 in. and are calcite filled; fractured rubble zone at 189' to 190'; thin green shale seam at 192.0' to 192.3'; lost 100 gal water at 189' to 190'; RQD=7.33/10.0=73%; 8 fractures in 10'.

While drilling, the following should be noted in the field:

- Length of core barrel and connectors.
- Number of drill rods (to accurately determine the length of a drill string).
- Core bit depth should be checked (length of drill string minus rod stickup equals the depth of the core bit).
- Note run time to determine coring rates.
- Record coring problems (for example, bit plugged at 106').
- Be aware of inconsistent rock types/mineralogies that may be present at the top of the first core run. Inconsistencies may indicate cobbles or

boulders on top of bedrock that may need to be cased off. A careful examination of rock cuttings from roller bit drilling is helpful.

LOGS IN PROJECT REPORTS

Example boring and test pit logs are contained in Appendix E.

Sheets describing the symbols and soil classification system used on the logs need to be included with project reports that contain logs. There are two standard Warzyn report insert sheets for this purpose. For both boring and test pits logs, the "Unified Soil Classification System" sheet should be included (Appendix F). The "Log of Test Boring--General Notes" sheet should also be included with boring logs (Appendix F).

Besides the Warzyn boring log format presented in Appendix E, there are other formats (gINT templates) available that are required for some projects. These include the Waste Management Inc. and Wisconsin Department of Natural Resources (Form 4400-122) formats. See the gINT SOP for details.

Geologic Symbols

A list of the material graphic symbols in use on gINT boring logs and on drawings for geologic cross sections is attached in Appendix G. This set of symbols is for use on all new projects. If additional work is being conducted on an older project, then make sure the symbols on the old and new logs are consistent. See the gINT SOP for specific use.

Water Levels and Cave In

Where possible, record the water level while drilling, before casing removal, after casing removal, and at times after drilling (such as 1/4 hr, 1 hr, 24 hr, 2 days, etc). If the borehole or test pit does not contain water, use the notation NW for no water rather than "dry".

Elevation
The measuring point for all samples should be taken as ground surface at the boring. If a drilling platform is more convenient, then the correction between the measuring point and ground surface is required for every depth measurement.

Record the ground surface elevation to the nearest 0.1 ft. Casing and pipe elevations for wells and piezometers are recorded to the nearest 0.01 ft. This is typically available by surveying after completion of the boring or well. Boring locations without wells should be restaked after completion of drilling to clearly mark the boring for surveying unless locations were surveyed and staked prior to drilling and the boring was performed at the staked location. If the borehole has caved, note the depth to cave-in and whether it was caved and moist, or caved and wet.

Drilling Dates
Note both the start and end dates on both the field and final logs (for example, drilling of some boreholes may take several days).

Rig Type
Note the type of drilling rig that was used, such as CME 75. Avoid using rig identification numbers that are assigned by a specific drilling company.

Initials of Personnel
Record the name or initials of the drilling company and crew chief, the borehole logger, and the professional who performed final editing of the log.

Drilling Method
Try to use only the drilling and sampling symbols shown on the "Log of Test Boring--General Notes" sheet in Appendix F. For example, WB is driller shorthand for wash boring. Our symbol on the final log would be RB/CW for roller/rock bit with clear water, or RB/DM if drilling mud was used (such as bentonite). Casing diameter and length should also be noted when casing is driven; for example, DC(4") 0-8', for 4-in. diameter casing driven to 8 ft. A typical drilling method description might consist of the following:

4 1/4" ID HSA 0-10', DC(6") 0-8', RB/CW 10.40', RC/HQ 40.50'

which indicates a hollow stem auger was used to drill to 10 ft, then casing was driven to 8 ft. The drilling method was switched to roller bits with clear water from 10 to 40 ft. From 40 to 50 ft, rock was cored with an HQ-size core barrel. Indicate when earth drilling is performed without sampling and indicate which other log, if any, has relevant descriptions from sampling. False starts and obstructions should also be noted.

Soil Sample Designation

For soil samples, record the sample number, type (such as split spoon or Shelby tube), recovery in inches, moisture (such as M for moist or W for wet), depth interval, and blow counts for split spoon samples. Do not use D for dry; dry means a moisture content of approximately 0% which is not the case for soils in the ground except possibly at the surface or for drilling in a desert. Do not use 'DAMP' or 'S' for Saturated. Sampler graphic symbols in use on gINT boring logs are attached in Appendix G. See the gINT SOP for specific use.

Blow counts are recorded for each 6 in. increment of drive of the split spoon (ASTM D1586). Usually the split spoon is driven a total of 18 in. for each sample. The SPT N-value is the sum of the blow counts recorded for the second and third 6 in. intervals. For example, blow counts of 5, 12, and 13 for a total of 18 in. of drive give an N-value of 25 blows/ft. If continuous samples are taken (24 in. of split spoon drive at 2 ft depth intervals), blow counts are recorded for each 6 in. increment, but the N-value is the sum of the counts from 6 to 12 in. and from 12 to 18 in. (again, the second and third increments). For example, blow counts of 5, 12, 13, and 14 for a total of 24 in. of drive give an N-value of 25 blows/ft. If a 3-in. diameter split spoon is used instead of the standard 2 in. split spoon, this should be noted on the log because the N-value is not a true SPT result. The SPT is defined in terms of blow counts from a 2 in. split spoon. Also record any frozen soil encountered because the frozen state may affect the SPT N-value that is obtained compared to the nonfrozen condition.

If refusal of the split spoon is encountered, then both the number of blows and inches of drive should be recorded. 100 blows in one foot or less is usually considered to be split spoon refusal. For example:

N-value=100/3" for 100 blows in the first 3 in.;
Blow counts of 33, 52, and 48/4" yield 100/10" for the N-value.

SOIL TEST RESULTS

Usually the unconfined compressive strength for cohesive soils, natural moisture content, Atterberg limits, P200 content, and loss-on-ignition values obtained for soil samples are recorded on boring logs when they are available. When several different laboratory tests are desired on a sample, multiple sample jars or containers are sometimes required.

Natural Moisture Content (W) and Loss on Ignition (LI)

These are recorded to the nearest 0.1% on the log. The typical sample volume required to perform these tests in the laboratory is about that of an 8-oz jar sample (i.e., split spoon sample size).

Atterberg Limits (LL and PL)

These values are reported to the nearest 1%. LL is liquid limit and PL is plastic limit. Plasticity index (PI) is determined by subtracting PL from LL. PI is not shown on the logs, but it is an important index parameter and should not be confused with PL. A minimum sample volume that is required to perform this test in the laboratory is about that of an 8-oz jar sample.

P200 Content (P200)

This value is reported to the nearest 0.1%. P200 content is the percent of material by weight passing the No. 200 U.S. standard sieve. P200 defines the amount of fines (clay and silt) in a soil sample. A minimum sample volume that is required to perform this test in the laboratory is about that of an 8-oz jar sample.

Other Laboratory Soil Tests
Usually other laboratory soil test results that may be determined, such as Proctor values and permeability (hydraulic conductivity), are not reported on the boring logs. It should be noted that sample volumes required for these tests are quite large (i.e., greater than an 8-oz jar or split spoon sample). Compositing of samples or obtaining auger samples, for example, to supplement split spoon samples may be necessary to achieve the required volume. Typically a minimum of 35 lb of soil are required for a Proctor test, or about the volume of a 5 gal pail. A permeability test maybe performed on a Shelby tube sample (relatively undisturbed specimen) or on a remolded specimen. If a remolded permeability test specimen is needed, then about 7 lb of soil should be obtained if the material is clay or silt, 12 lb if the material is fine sand, and 5 gal if the material is sand and gravel.

If Shelby tube samples are obtained, they require special handling to maintain the relatively undisturbed state. Seal the tubes against moisture loss, store in an upright position, protect against shaking/vibration, and protect from freezing temperatures. Tube samples should only be shipped in special crates or boxes designed to minimize vibration disturbance.

Submittal of soil samples for testing will be covered in more detail in an SOP for the Warzyn Geotechnical Laboratory.

[mad-sop-247]

TABLES

TABLE 1

FIELD IDENTIFICATION TESTS FOR COHESIVE SOILS

Plasticity
Add water or allow to dry sufficiently until the soil can be worked in the hands and remolded without sticking to the fingers. Roll a piece of soil, about the size of a caramel, in your hand into a thread approximately 1/8 in. in diameter.

High Plasticity Clay (Fat Clay)

Thread can be remolded into a ball and the ball easily deformed without cracking or crumbling.

High Plasticity Silt (Elastic Silt)

Thread can be remolded into a ball and the ball deformed, but the ball will crack slightly and resist deformation.

Low Plasticity Clay (Lean Clay)

Thread can be remolded into a ball, but the ball will crack and easily crumble under pressure.

Low Plasticity Silt (Silt)

Thread cannot be remolded into a ball without completely breaking apart.

Organic Soils (Organic Silt or Clay)

Soils containing organic materials will form soft spongy threads or balls.

Dilatancy
Dilatancy of soils, or the release of moisture upon agitation, indicates low to non-plastic materials. Dilatancy can be determined by adding sufficient water until the soil is quite sticky. A pat of soil is placed in the palm and jarred against the other hand. The soil is said to have given a reaction when water comes to the surface, producing a shiny appearance. Upon squeezing the sample, the surface water will disappear, giving a dull surface. Because it is rare to find silt or fine-grained samples without some amount of clay, there are varying degrees of reaction:

Sudden Reaction -	Typical of non-plastic fine sands or silt.
Slow Reaction -	Indicates a slight plasticity such as might be found in silty clays or organic silts.
No Reaction -	Indicates clays.

TABLE 1

Dry Strength

Mold a pat of soil to about the consistency of putty by adding water as necessary. Allow the pat to completely dry and then test the crushing strength by breaking or crumbling between the fingers:

High Plasticity Clay (Fat Clay) - High crushing strength

High Plasticity Silt (Elastic Silt)
and Low Plasticity Clay (Lean Clay) - Less crushing strength

Silts, Organic Soils and Silty Fine Sands - Very low to no crushing strength.

Sedimentation

Place a palm full of representative soil into a glass sample jar and fill with water. Vigorously shake for about one minute and allow to stand:

Gravel and Coarse Sand - Will settle instantly

Medium to Fine Sand - Will settle in 1 to 3 minutes

Silt - Will settle within about 15 minutes

Clay - Will take slightly longer than 15 minutes

The relative thickness of the sediments is an indication of the percentages of the various grain sizes.

Feel

Sandy - Rough and gritty.

Silty - Not particularly gritty, but noticeable. Dry soil on hands will easily scrape off.

Clayey - Smooth texture. Dry soil on hands will not easily scrape off.

Shine

High Plasticity - Will give a definite shine when a moistened sample is rubbed with the fingernail.

Low Plasticity - Will give a dull appearance.

Note: Refer to ASTM D2488 for further details.

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TABLE 3

ROCK DESCRIPTION COMPONENTS

A. Weathering

Fresh	Rock fresh, crystals bright, few joints may show slight staining.
Very slight	Rock generally fresh, joints stained, some joints may show thin clay coatings, crystals in broken face show bright.
Slight	Rock generally fresh, joints stained, and discoloration extends into rock up to 1 in. Joints may contain clay. In granitoid rocks, some scattered feldspar crystals are dull and discolored.
Moderate	Significant portions of rock show discoloration and weathering effects. In granitoid rocks, most feldspars are dull and discolored; some show clayey.
Moderately severe	All rock except quartz discolored or stained. In granitoid rocks, all feldspars dull and discolored and majority show kaolinization. Rock shows severe loss of strength.
Severe	All rock except quartz discolored or stained. Rock "fabric" clear and evident, but reduced in strength to strong soil. In granitoid rocks, all feldspars kaolinized to some extent. Some fragments of strong rock usually left.
Very severe	All rock except quartz discolored or stained. Rock "fabric" discernible, but mass effectively reduced to "soil" with only fragments of strong rock remaining.
Complete	Rock reduced to "soil." Rock "fabric" not discernible or discernible only in small scattered locations. Quartz may be present as dikes or stringers.

B. Color

C. Structure

1. Massive - Homogeneous Structure
2. Stratified - Layered Strata ≥ 1 cm
3. Foliated - Metamorphic: Parallel Fabric Fine Grained

4. Schistosity - Metamorphic: Parallel Fabric Coarse Grained
5. Jointed - Vertical or transverse fracture along which no movement has occurred.
6. Laminated - Layering ≤ 1 cm
7. Sparitic - Coarse Crystalline Texture
8. Micritic - Very Fine Crystalline Texture

Joint Bedding and Foliation Spacing in Rock

Spacing	Joints	Bedding and Foliation
Less than 2 in.	Very close	Very thin
2 in.-1 ft	Close	Thin
1 ft-3 ft	Moderately close	Medium
3 ft-10 ft	Wide	Thick
More than 10 ft	Very wide	Very thick

Joint spacing refers to the distance normal to the plane of the joints of a single system or "set" of joints that are parallel to each other or nearly so. The spacing of each "set" should be described, if possible to establish.

D. Rock Type: Dolomite, sandstone, granite, mica-schist, etc.

E. Vertically or horizontally fractured zones.

F. Scattered Occurrences - Chert lenses or seams, pyrite, calcite-filled or vacant vugs, shale seams, pitting, fossiliferous zones, etc.

G. Coring Information - Report as much information as possible.

Most Important:

Beginning of run
End of run
Run number
% recovery
% rock quality designator (RQD)
Fracture frequency (e.g., fractures/ft)
Water loss
Core loss in inches
Core gain in inches

Less Important:

Drilling time
Hydraulic pressure
Water pressure
Revolutions per min (rpm)
Drilling rate (ft/min)
Drilling action

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Scope and Application: This method is applicable to the installation of groundwater monitor wells

References: ASTM Standard D5092-90;
In Wisconsin: Chapter NR 141, Wisconsin Administrative Code;

I. PRE-FIELD CHECKLIST

A. Health and Safety Plan

B. Well construction plan

1. Well materials
2. Well depths
3. Conceptual hydrogeologic model
4. Objective for installing well. Why in that location? Why that depth?

C. Inform driller of the well construction plan

D. Electric water level indicator

E. Tape measure graduated in tenths and hundredths of a foot

F. Warzyn standard locks

G. Well construction forms

H. Traffic cones

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II. Checklist of Items to be Inspected

A. Before well installation

1. Measure static water level or estimate water level from wet soils.

2. Measure borehole depth.

3. Is the borehole stabilized? A soil borehole should be cased with temporary drill casing or augers. Do not set a well through an open hole after pulling out the augers. Open boreholes in stable bedrock, within one aquifer, are permitted.

4. New well materials: no used well screen, riser, or caps.

5. Steam clean well materials inside and outside; wrap in plastic or store in a clean area; handle well materials with clean gloves.

6. Inspect screen and riser pipe inside and out for cleanliness, defects, gouges, cracks: reject any failed pieces.

7. Accurately measure length of screen piece including blank sections and well point.

8. Measure total length of slotted interval.

9. Prepare a sketch which accurately represents the screen piece showing lengths of blank interval, lengths of slotted interval, well point, etc. Measurements must be in tenths of feet.

10. Accurately measure length of each riser piece.

11. Count the number of riser pieces.

12. Determine the total length of the assembled well string.

13. Inspect filter pack material: proper gradation, proper material, contaminant free, sufficient quantity.

14. Inspect fine sand material: proper gradation, proper material, contaminant free, sufficient quantity.

15. Inspect bentonite: 100% pure Wyoming bentonite with no additives, proper size, sufficient quantity.

16. Optional: inspect portland cement, proper type and sufficient quantity. Caution: Use of Portland cement may result in grout contamination of the well (high pH) if improper seals and/or improper recipes are used. Consult with project hydrogeologist.

17. Inspect tremie pipe: proper size and sufficient quantity; steam cleaned.

18. Stick-up well protective pipe: metal casing 2 in. dia greater than the well casing; minimum 5 ft length with locking cap.

19. Flush mounted protective cover pipe: water tight metal casing 4 in. dia greater than the well casing; minimum 12 in. length; exterior flange or lugs; water tight, bolt down lid with the words 'MONITORING WELL' on its outer surface.

20. Optional: (if necessary) place bentonite seal below filter pack using a tremie pipe; use this option when the borehole is greater than 5 ft deeper than depth of the well. Use a 2 in. dia well riser pipe as a tremie pipe set into the borehole below the well screen. Slowly place bentonite chips through the tremie pipe while checking for bridging. Bring the chips up to within 2 ft of the well

bottom. The tremie pipe allows placement of the seal without smearing bentonite at the screen interval and prevents losing the borehole should bridging occur.

B. During well installation

1. Determine depth of well placement as total length of assembled well string minus height of well string top above ground surface.

2. Riser pieces should have water tight joints: either neoprene gaskets or teflon tape. Do not use glue or solvent cement.

3. Accurately determine total well depth.

   a. Measure length of well riser pipe piece cut off from the total length of well string.

   b. Total well string length minus length of cut off piece equals total well depth (TD) measured from top of casing (TOC).

   c. The well top should stick up a minimum of 24 in. aboveground surface.

4. Install a temporary well cap to prevent any materials from falling into the well.

5. Filter pack construction.

   a. Introduce a well graded sand in a controlled manner: slowly add filter sand while retracting augers or casing.

   b. Driller continuously uses a tape measure to check for bridging.

c. Filter pack will extend from 6 in. below the well bottom to 2 ft above top of well screen.

d. Record volume of sand placed along with manufacturer, brand name, and gradation; 50 lbs of sand is approximately 0.5 cf.

e. Record depth to top of sand pack.

6. Collapsed formation (option): May be used when an artificial sand pack cannot be installed and when the collapsed formation is coarser than fine sand. The collapsed formation should be analyzed for grain size and specific gravity.

7. Filter pack seal construction.

   a. Introduce a well graded fine sand in a controlled manner.

   b. Driller continuously uses a tape measure to check for bridging.

   c. Place 2 ft of fine sand; record the volume of fine sand placed along with manufacturer, brand name, and gradation; 50 lbs of sand is approximately 0.5 cf.

   d. Record the depth to the top of the fine sand pack.

   e. Check that the well is not being pulled up nor is it sinking as installation progresses.

   f. Wells having grouts or slurry as the annular space sealant will have a minimum 5 ft of bentonite seal placed above the fine sand.

   Bentonite Seal:

(1) Use bentonite chips or pellets no larger than 3/8 in. dia when placing the seal through water.

(2) Granular bentonite may be used when the depth of placement is less than 25 ft and when no standing water is in the borehole.

(3) Seals above the water table will be placed and hydrated in 2 ft lifts; use a tremie pipe to place either the bentonite or the water to prevent a thick cake of bentonite from forming in the augers.

(4) Place 6 in. of fine sand on top of the bentonite seal.

(5) Record the type, size, and volume of sealant placed.

8. Annular space seal: all permanent monitoring wells will have an annular space seal which extends from the top of the filter pack seal to the bottom of the ground surface seal and will have a minimum 2 ft length.

   a. For water table wells with the water table at 7 ft or less below ground surface use granular bentonite only; place the bentonite in 2 ft lifts, hydrating each lift.

   b. Use thick bentonite slurry or bentonite-cement grout for placing annular space seal greater than 50 ft deep. Caution: Use of Portland Cement may result in grout contamination of the well (high pH) if improper seals or improper recipes are used. Consult with the project hydrogeologist.

   (1) Bentonite slurry recipe: 2 lb of granular bentonite per gal of water, or as thick as the driller can pump it; Rule of

thumb: Thick slurry tends to shear in the mud tub rather than flow.

(2) Bentonite-cement grout recipe: It is important to closely follow this recipe; deviation from this recipe may result in grout contamination of the well. Mix 6 1/2 gal of water per 94 lb bag of Portland Type I cement then add 3 to 5 lb of bentonite powder. This will yield about 1 1/2 times the volume of water used. Carefully measure the amount of water: Too much water causes persistent pH problems in the well (grout contamination).

(3) Tremie pump sealant from the bottom up using a side discharge tremie pipe. Pump the sealant until it flows full strength, undiluted, up and out thru the top of the hole.

(4) Allow a 12-hour period between installing slurry or grout and installing the protective casing to allow for settlement and curing. If a 12-hr waiting period is impractical, the slurry or grout should be bailed out down to the water table. The annular space should then be filled using bentonite chips, pellets, or granules as described below.

(5) The top of the seal should not be higher than 5 ft below ground surface - remove excess grout by bailing it out before it sets up.

(6) Avoid using bentonite slurry as annular space sealant in the unsaturated zone. Bentonite slurry will flow into the unsaturated zone leaving a void space in the unsaturated

annular space. Pump slurry to the top of the borehole, let it settle for 12 hours, then use "c" or "d" below.

c. Use bentonite chips no larger than 3/8 in. dia or bentonite pellets when there is less than 30 ft of standing water in the borehole and the depth to the bottom of the annular space seal is less than 50 ft (except when the depth to water table is less than 7 ft use granular bentonite). Place pellets or chips slowly in a controlled manner. Check for bridging. Hydrate in the unsaturated zone.

d. Use granular bentonite.

(1) When there is no standing water in the borehole and the placement depth is less than 25 ft.

(2) The depth to the water table is less than 7 ft below ground surface.

e. Record type and volume of annular space seal.

9. Construct ground surface seal. Check for annular space seal settlement. If grout or slurry is used as the annual space seal, wait 24 hr after seal installation before installing the surface seal.

a. Stick up well protective pipe.

(1) Measure the length of well protective pipe.

(2) Subtract well stick up height to get embedment depth of well protective pipe.

(3) If the well protective pipe embedment depth intersects the filter pack or filter pack seal, then shorten the length of the well protective pipe. The minimum embedment depth should not be less than the stick up height.

(4) The ground surface seal will start at least 5 ft below ground surface.

(5) Place bentonite chips, pellets or granules up to 1 ft below the well protective pipe embedment depth, then place 1 ft of filter sand.

(6) Set the well protective pipe onto the firm bed of filter sand.

(7) Add granular bentonite around the outside of the protective pipe only and hydrate it in 2 ft lifts to the surface.

(8) Concrete ground surface seals in regions where the ground freezes are not recommended. Frost heave will jack the concrete seal and the well protective pipe out of the ground. If it is necessary to construct a concrete ground surface seal in regions affected by freezing ground, the concrete should be at least 4-ft dia, 8-in. thick, with reinforced mesh poured onto 4-in. of compacted road gravel. The concrete should not be poured onto fine grained soils nor should it be in contact with bentonite. The concrete should be sloped radially away from the well casing. Concrete should not be in contact with the well casing. This may seem excessive, but anything less is very likely to be ruined by frost action.

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(9) Do not place bentonite between the protective pipe and the well casing.

(10) If the monitoring well depth is such that both a minimum 2 ft annular space seal and a minimum 5 ft ground surface seal cannot both be placed, the ground surface seal may be shortened.

(11) Record the depth to the bottom of the ground surface seal, also record the length and dia of the well protective pipe.

(12) The well protective pipe should stick up a minimum of 24 in. above the ground surface and should always extend above the top of the well.

(13) The top of the well pipe must be within 4 in. of the top of the well protective pipe.

(14) The well protective pipe should not extend into the annular space seal nor into the filter pack.

(15) The well protective pipe should be filled with filter sand to within 12 in. of the top of the well.

(16) A weep hole may be drilled into the well protective pipe; a small vent hole should be cut or drilled into the well cap.

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b. Flush mount wells.

(1) Install only in areas of high vehicular traffic.

(2) Do not install in areas subject to ponding or flooding and should not be installed directly down topographic slope from surficial contamination.

(3) Install through an impervious surface such as asphalt or concrete; if an impervious surface does not exist, one should be created such as a 4-ft dia reinforced concrete pad, 8 in. thick poured onto 4 in. of compacted road gravel (Really!).

(4) Granular bentonite should fill the borehole annular space from the top of the annular space seal to 3 ft below ground surface, then a bed of filter sand should be placed.

(5) The flush mount well protective casing should rest on a firm bed of filter sand.

(6) Concrete should be placed around the outside of the flush mount well protective casing and it should be positioned slightly (1/8 in.) above grade with the concrete sloping radially outward.

(7) There should be no more than 8 in. between the top of the well casing and the top of the flush mount well protective casing.

(8) Flush mount wells should be installed with water tight locking well caps.

C. After well installation

1. Check for settlement of the ground surface seal; top off as necessary.

2. Label the protective casing with the well number.

3. Stick up wells: label the well cap inside and out with the well number.

4. Lubricate the well lock.

    a. Do not use WD-40 nor penetrating oils.

    b. Remove the lock away from the well and lubricate it with liquid graphite.

    c. Wipe off excess lubricant, allow the lock to 'dry', then return it to the well.

5. Flush mount wells.

    a. Use a tape measure to accurately locate the well with reference to at least two permanent land marks (e.g., 20 ft west and 11 ft north of fire hydrant; 22 ft due east of power pole).

6. Stick up wells in high traffic areas: consider placing bumper posts around the well.

    a. Wood or steel, set in concrete or bentonite.

    b. At least 8 ft long with 4 ft stick up.

c. Posts may be painted or flagged.

d. Do not paint the well protective casing.

7. Stick up wells in agricultural fields:

a. Securely attach a 10 ft x 3/4 in. PVC pipe (or equivalent) to the well protective casing using large hose clamps.

b. Locate the well by measuring distance from fence lines or landmarks.

8. Clean up the area: pick up trash, do not burn; pick up cuttings; use a broom, rake, or hose down the area.

III. FIELD DOCUMENTATION

A. Stick up Monitoring Well Construction Summary (See Attachment)

1. Use for stick up wells.

2. Readily adapts to Wisconsin Form 4400-113A.

3. Utilized for field and for inclusion in report.

4. Supplemented by Monitoring Well Construction Field QC Summary (See Attachment).

B. Flush Mount Monitoring Well Construction Summary (See Attachment)

1. Use for flush mount wells.

2. Readily adapts to Wisconsin Form 4400-113A.

3. Utilized for field and for inclusion in report.

4. Supplemented by Monitoring Well Construction Field QC Summary (See Attachment).

C. Waste Management

1. Monitor well construction summary (See Attachment).

2. Used for both field and final client issue.

3. Use in conjunction with one of Warzyn's forms.

4. Supplemented by Well Installation QC Form.

IV. TYPICAL WELL DESIGN

A. Water table wells (See Attachment)

1. 10 ft screen length (no more than 15 ft).

2. Measure static water level or estimate from wet soil sample.

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3. Set screen to intersect water level.

    a. 7 ft under, 3 ft above at 'dry' times; 8 ft under 2 ft above during 'wet' times.

    b. All under water when the water table is less than 5 ft below ground.

    c. May need to have much less than 7 ft under water for perched water table conditions to avoid poking a hole in the underlying confining layer. A shorter well screen may need to be installed in thin, shallow perched zones.

4. Construct filter pack and filter pack seal.

5. Construct annular space seal.

    a. Greater than 50 ft: consult with project hydrogeologist.

    b. 50 ft to 25 ft: use bentonite pellets or chips in 2 ft lifts; hydrate every lift; use a tremie pipe for water or chips to prevent a thick bentonite cake from forming in the augers or casing.

    c. 0 to 25 ft: use granular bentonite or pellets or chips in 2 ft lifts; hydrate every lift; use a tremie pipe for water or bentonite to prevent a thick bentonite cake from forming in the augers or casing.

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6. Ground surface seal and well protective casing.

   a. Stick up wells with water table greater than 7 ft deep.

      (1) With 8 ft long well protective casing, start the ground surface seal at 6 ft (less deep for shorter well protective casings); set the protective casing on a bed of filter sand, add a little more sand if necessary; place granular bentonite around the well protective casing and hydrate it in 2 ft lifts; do not place bentonite inside the well protective casing; do not use concrete in areas subject to freezing temperatures.

   b. Stick up wells with water table less than 7 ft deep:

      (1) Use shorter well protective casing (5 ft minimum).

      (2) Start ground surface seal at 6 in. below the bottom of the well protective casing; place 6 in. of filter sand then set the well protective casing onto the sand; add granular bentonite or bentonite chips around the outside of the well protective casing and hydrate it in 2 ft lifts; do not place bentonite inside the well protective casing; do not use concrete in areas subject to freezing temperatures.

   c. Flush mounted casing.

      (1) Start the ground surface seal at 5 ft depth.

      (2) Place granular bentonite or bentonite chips in 2 ft lifts and hydrate in place up to 2 ft; from 2 ft to 1 ft add filter sand; place an old tyvek or trash bag over the filter sand, then use a chisel or other tool to enlarge the borehole to

4 in. dia greater than the outside dia of the flush mount well box; make the walls of the hole vertical, not tapered; remove excess materials and the tyvek/trash bag; place the flush mount well box onto the sand and center it; add or remove sand as necessary so the top of the flush mount well box is slightly above grade (< 1/8 in.); mix concrete in a bucket or in a wheel barrel, <u>do not mix it on the pavement</u>, add just enough water to make it plastic but not runny; place concrete around the outside of the flush mount well box in rodded 6 in. lifts; form up and puddle the concrete surface with a trowel so it slopes radially outward from the flush mount well box cover; lock the well and place bolt down cover; protect from freezing with temporary cardboard cover; protect from traffic using traffic cones.

B. Piezometers

1. Maximum 5 ft screen length.

2. Depth depends on objectives specified in the well construction plan, and geology encountered.

3. May need to backfill the borehole to an appropriate depth using a bentonite seal below well screen. Use a tremie pipe.

4. The well screen and sand pack should be within one aquifer, not extended across a confining layer to connect two aquifers. The bentonite seal should be tied into a low permeability unit (if possible).

5. Construct filter pack and filter pack seal.

6. Construct annular space seal; calculate the volume of sealant needed to fill the hole from the top of the filter pack seal to the ground surface.

   a. Greater than 50 ft deep with predominantly non-cohesive soils or granular bedrock.

      (1) Mix thick granular bentonite slurry and tremie-pump it to the top using a side discharge tremie pipe.

      (2) The drill casing or augers should be fully charged with thick slurry before starting to remove augers or casing.

      (3) Top off grout level from the surface as each section of auger or casing is removed.

      (4) Use a mix recipe such as: 2 lbs of granular bentonite per gallon of water, or as thick as the driller can pump it; rule of thumb: Thick enough when it tends to shear in the mud tub rather than flow.

   b. Greater than 50 ft deep with predominantly cohesive soils or tight bedrock.

      (1) Mix a batch of thick granular bentonite slurry as described in (4) above sufficient to fill the lower 25 ft of the annular space.

      (2) Tremie pump the slurry from the bottom up using a side-discharge tremie pipe.

      (3) Mix bentonite-cement grout by closely following this recipe: 6 1/2 gallons water plus 94 lbs portland Type 1

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cement plus 3 lbs bentonite powder to yield approximately 1 1/2 times the gallons of water used. Carefully measure the water volume used; too much water causes pH problems in the well. CAUTION: Use of portland cement may result in grout contamination of the well (high pH) if improper seals and/or improper recipes are used. Consult with the project hydrogeologist.

(4) Pull back the tremie pipe to 15 ft above its former level and tremie pump until thick bentonite-cement grout flows out the top.

(5) The drill casing or augers should be fully charged with bentonite slurry and bentonite-cement grout before starting to remove augers or casing.

(6) Top off grout settlement from the surface as each section of augers or casing is removed.

(7) If the grout level hasn't settled after removing all casing and augers; then bail out grout until it is below 6 ft.

c. Annular space seals less than 50 ft deep.

(1) Use bentonite slurry or bentonite-cement grout in the saturated zone as described above, or

(2) Use bentonite pellets chips or granular bentonite as described in Part IV.A No.5. above

WARZYN

FLUSH MOUNT MONITORING WELL CONSTRUCTION SUMMARY

JOB NO.

Facility/Project Name

Local Grid Location of Well
☐ N. ☐ E.
ft. ☐ S. ft. ☐ W.

Well Name

Type of Well
Water Table Observation Well ☐
Piezometer ☐

Grid Origin Location
Lat. ______ Long. ______ or
St. Plane ______ ft. N. ______ ft. E.

Date Well Installed

Section Location of Waste/Source ☐ E. ☐ W.

Well Installed By: (Person's Name and Firm)

Distance Well Is From Waste/Source Boundary
ft.

Location of Well Relative to Waste/Source
☐ Upgradient ☐ Sidegradient
☐ Downgradient ☐ Not Known

(Geologist)

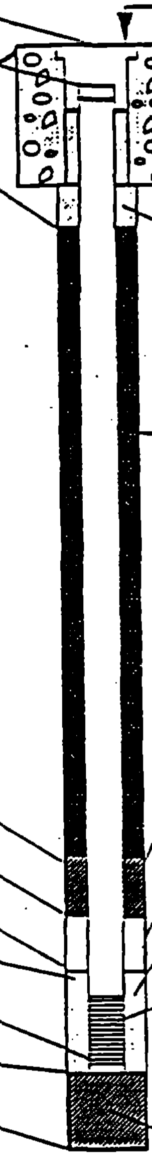
(Driller)

Watertight Cover elevation ______ ft. MSL

Well casing top elevation ______ ft. MSL

Land surface elevation ______ ft. MSL

Surface Seal, bottom ______ ft. MSL or ______ ft.



Bolt down water tight cover:
Inside Diameter: ______ (in.) Length ______ (in.)

Water tight well cap? Yes ☐ No ☐
Lock? Yes ☐ No ☐

Surficial Seal: Concrete ☐
Bentonite ☐

Sand Drainage? Yes ☐ No ☐

USCS classification of soil near screen:
GP ☐ GM ☐ GC ☐ GW ☐ SW ☐ SP ☐
SM ☐ SC ☐ ML ☐ MH ☐ CL ☐ CH ☐
Bedrock ☐

Sieve analysis attached? ☐ Yes ☐ No

Drilling method used: Rotary ☐
Hollow Stem Auger ☐
Other ☐

Drilling fluid used: Water ☐ Air ☐
Drilling Mud ☐ None ☐

Drilling additives used? ☐ Yes ☐ No

Describe ______

Source of water:

Material between well casing and protective pipe:
Bentonite ☐
Annular space seal ☐
Other ☐

Annular space seal: Granular Bentonite ☐
______ Lbs/gal mud weight... Bentonite-sand slurry ☐
______ Lbs/gal mud weight............ Bentonite slurry ☐
______ % Bentonite............ Bentonite-cement grout ☐
______ cu ft volume added for any of the above

How installed: Tremie ☐
Tremie pumped ☐
Gravity ☐

Bentonite seal: Bentonite granules ☐
☐ 1/4 in. ☐ 3/8 in. ☐ 1/2 in. Bentonite pellets ☐
Other ☐

Fine sand material: Manufacturer, product name & mesh size

Volume added ______ cu ft

Filter pack material: Manufacturer, product name & mesh size

Volume added ______ cu ft

Well casing: Flush threaded PVC schedule 40 ☐
Flush threaded PVC schedule 80 ☐
Other ☐

Screen material:

Screen type: Factory cut ☐
Continuous slot ☐
Other ☐

Manufacturer ______

Slot size: ______ in.

Slotted length: ______ ft.

Backfill material (below filter pack): None ☐
Other ☐

	ELEVATION		DEPTH	
Bentonite seal, top	_____	ft. MSL or	______	ft.
Fine sand, top	_____	ft. MSL or	______	ft.
Filter pack, top	_____	ft. MSL or	______	ft.
Screen joint, top	_____	ft. MSL or	______	ft.
Well bottom	_____	ft. MSL or	______	ft.
Filter pack, bottom	_____	ft. MSL or	______	ft.
Borehole, bottom	_____	ft. MSL or	______	ft.
Borehole, diameter	_____	in.		
O.D. well casing	_____	in.		
I.D. well casing	_____	in.		

I hereby certify that the information on this form is true and correct to the best of my knowlege.

Signature

Firm
Warzyn Inc.

IPRIOR/FLUSH

WARZYN

STICK-UP MONITORING WELL CONSTRUCTION SUMMARY

JOB NO.

Facility/Project Name	Local Grid Location of Well ft. ☐ N. ☐ S. ft. ☐ E. ☐ W.	Well Name
Type of Well Water Table Observation Well ☐ Piezometer ☐	Grid Origin Location Lat. ______ Long. ______ or St. Plane ft. N. ft. E.	Date Well Installed
	Section Location of Waste/Source ☐ E. ☐ W.	Well Installed By: (Person's Name and Firm)
Distance Well Is From Waste/Source Boundary ft.	Location of Well Relative to Waste/Source ☐ Upgradient ☐ Sidegradient ☐ Downgradient ☐ Not Known	(Geologist) (Driller)

Protective pipe, top elevation ______ ft. MSL

Well casing top elevation ______ ft. MSL

Land surface elevation ______ ft. MSL

Surface Seal, bottom ______ ft. MSL or ______ ft.

USCS classification of soil near screen:
GP ☐ GM ☐ GC ☐ GW ☐ SW ☐ SP ☐
SM ☐ SC ☐ ML ☐ MH ☐ CL ☐ CH ☐
Bedrock ☐

Sieve analysis attached? ☐ Yes ☐ No

Drilling method used: Rotary ☐
Hollow Stem Auger ☐
______ Other ☐

Drilling fluid used: Water ☐ Air ☐
Drilling Mud ☐ None ☐

Drilling additives used? ☐ Yes ☐ No

Describe ______

Source of water:

______

	ELEVATION	DEPTH
Bentonite seal, top	______ ft. MSL or	______ ft.
Fine sand, top	______ ft. MSL or	______ ft.
Filter pack, top	______ ft. MSL or	______ ft.
Screen joint, top	______ ft. MSL or	______ ft.
Well bottom	______ ft. MSL or	______ ft.
Filter pack, bottom	______ ft. MSL or	______ ft.
Borehole, bottom	______ ft. MSL or	______ ft.

Borehole, diameter ______ in.

O.D. well casing ______ in.

I.D. well casing ______ in.

Cap and lock? ☐ Yes ☐ No

Protective cover pipe:
Inside diameter: ______ in.
Length: ______ ft.
Material: Steel ☐
Other ☐

Additional protection? ☐ Yes ☐ No
If yes, describe: ______

Surface seal: Bentonite ☐
Concrete ☐
Other ☐

Material between well casing and protective pipe:
Bentonite ☐
Annular space seal ☐
Other ☐

Annular space seal: Granular Bentonite ☐
______ Lbs/gal mud weight... Bentonite-sand slurry ☐
______ Lbs/gal mud weight............ Bentonite slurry ☐
______ % Bentonite............ Bentonite-cement grout ☐
______ cu ft volume added for any of the above

How installed: Tremie ☐
Tremie pumped ☐
Gravity ☐

Bentonite seal: Bentonite granules ☐
☐ 1/4 in. ☐ 3/8 in. ☐ 1/2 in. Bentonite pellets ☐
Other ☐

Fine sand material: Manufacturer, product name & mesh size

______

Volume added ______ cu ft

Filter pack material: Manufacturer, product name & mesh size

______

Volume added ______ cu ft

Well casing: Flush threaded PVC schedule 40 ☐
Flush threaded PVC schedule 80 ☐
Other ☐

Screen material: ______

Screen type: Factory cut ☐
Continuous slot ☐
Other ☐

Manufacturer ______

Slot size: ______ in.

Slotted length: ______ ft.

Backfill material (below filter pack): None ☐
Other ☐

I hereby certify that the information on this form is true and correct to the best of my knowlege.

Signature	Firm Warzyn Inc.

IPRIOR/STICKUI

Well No. ______

Boring No. X-Ref: ______

MONITOR WELL CONSTRUCTION SUMMARY

Survey Coords: ______

______

Elevation Ground Level ______

Top of Casing ______

Drilling Summary:

Total Depth ______

Borehole Diameter ______

Casing Stick-up Height: ______

Driller ______

______

______

Rig ______

Bit(s) ______

______

Drilling Fluid ______

______

Protective Casing ______

Construction Time Log:

Task	Start Date	Start Time	Finish Date	Finish Time
Drilling				
Geophys. Logging:				
Casing:				
Filter Placement:				
Cementing:				
Development:				

Well Design & Specifications

Basis: Geologic Log ____ Geophysical Log ____

Casing String (s): C = Casing S = Screen.

Depth	String(s)	Elevation
-		-
-		-
-		-
-		-
-		-

Casing: C1 ______

______

C2 ______

______

Screen: S1 ______

______

S2 ______

Filter Pack: ______

______

______

Grout Seal: ______

______

______

Bentonite Seal: ______

______

______

Well Development:

______

______

______

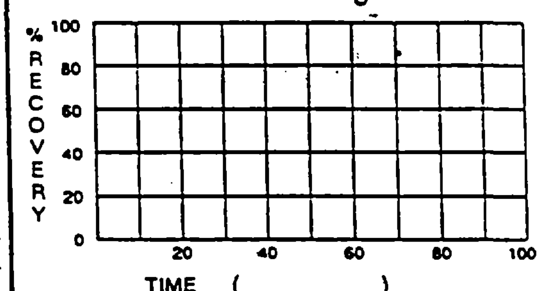
______

Stabilization Test Data:

Time	p H	Spec. Cond.	Temp (C)

Recovery Data:

Q= S_o=



Comments: ______

______

______

______

SITE NAME ______

LOCATION

WC 7000

SUPERVISED BY ______

DATE

MONITORING WELL CONSTRUCTION FIELD QC SUMMARY

WARZYN

Job Name ______________________ Job No. ______________________

Location ______________________ Well No. ______________________

Personnel ______________________ Date ______________________

BOREHOLE WATER LEVELS		
DEPTH	DATE	TIME

Lock Number ______________

Lock Lubricated?	Yes ☐ No ☐	Screen & Riser Steamed?	Yes ☐ No ☐
Vented Cap?	Yes ☐ No ☐	Pipe Joints Sealed?	Yes ☐ No ☐
Weep Hole Drilled?	Yes ☐ No ☐	Check for Seal Settlement?	Yes ☐ No ☐
Screen Inspected?	Yes ☐ No ☐	Well Labelled?	Yes ☐ No ☐
Riser Pipe Inspected?	Yes ☐ No ☐	Well Located?	Yes ☐ No ☐

Well Installation Data

Riser Piece Length		Number		Length
________ ft	x	________	=	________ ft
________ ft	x	________	=	________ ft
________ ft	x	________	=	________ ft

Total Riser Length ________ ft

Misc. Length (Sub, Cap, Plug) + ________ ft

Well Screen Piece Length + ________ ft

Total String Length ________ ft

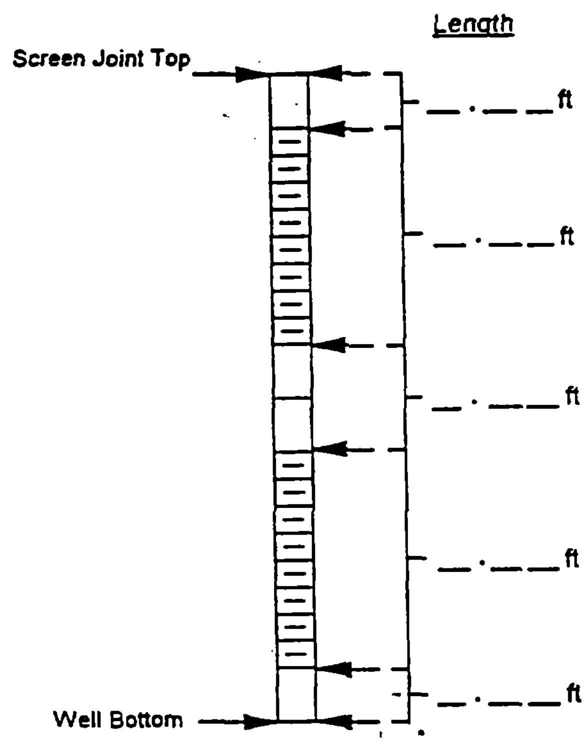
Cut Off Length - ________ ft

Total Well Depth (TOC) ________ ft

Well Stick Up (or Well Stick Down +) - ________ ft

Well Bottom Depth (Ground Surface) ________ ft

Well Screen Piece Detail



Well Screen Piece Length __ __ . __ __ ft

IW-MWCQCI

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Subject: Monitor Well Development

Method: Surge and Purge Using a Bailer and/or Pump

Reference: ASTM D5092
In Wisconsin: Chapter NR 141 Wisconsin Administrative Codes
For Waste Management Inc.: See Site Assessment Manual

Well development should not occur within 24 hr after well construction if annular space is grouted. Grout must set up prior to development.

I. PRE-FIELD CHECKLIST

A. Paperwork to take to the site

1. Completed monitoring well construction field QC summary for the wells to be developed

2. Completed monitoring well construction summary for the wells to be developed

3. Monitoring well development summary forms

4. Health and Safety Plan

B. Estimate well recovery rate - based on boring log or other observations

1. Fast - Surge with a bailer, then bail or pump

2. Slow - Limited bailer development

C. PVC bailer and cable

D. Plastic sheeting

E. Electronic water level indicator

F. 5 gallon bucket

G. Plan for disposal of purge water

H. Decon solutions

I. pH meter

J. Specific conductivity meter

K. Pumps (optional)

1. GRUNDFOS Pump
2. B-K Pump
3. Pitcher Pump

L. PVC riser extension (flush mount wells)

M. Hand tools (socket set, hammer)

N. Sample bottles, preservatives

O. Well access - (keys, flush mount access, off-site property access agreement)

II. FIELD CHECKLIST

A. Well labelled?

B. Surficial seal in good shape?

C. Flush mount cover or protective casing in good shape?

D. Lock in good shape? Lubricated with graphite?

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E. Sand drainage inside flush mount of protective casing?

F. Vent hole in well cap? (stick up wells)

G. Water tight cap loosened, water level equilibrated? (flush mount wells)

H. Weep hole in protective casing?

III. METHOD FOR WELLS THAT CANNOT BE PURGED DRY

A. Measure depth to water from top of well casing

B. Measure total well depth from top of well casing

C. Compare measured total well depth to total well depth reported on the QC Summary. The difference is the amount of sediment in the well bottom

D. Calculate the total volume of water contained in the well plus the volume of water in the sand pack:

Total Volume = well volume + sand pack volume
Well volume (gallons) = $0.16 (r^2)(L)$
Where r = inside well radius in inches
L = length of water column in feet

Sand Pack Volume (Gallons) = $0.057(R^2 - r^2)L$
Where R = borehole radius in inches
r = outside well radius in inches
L = saturated length of sand pack in feet
(assumes sand pack porosity of 35%)

E. Alternatively surge and purge the well using a PVC bailer. Let the bailer sink to the well bottom. Forcefully pull it up through the screen length and let it settle back to the bottom. This agitation suspends sediment in the well bottom

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and moves fines in and out of the well screen. Pull out the bailer and discharge the water into a 5 gallon bucket. Note the color, odor, and turbidity of the purge water. Repeat this surge and purge cycle for about 30 minutes.

F. After surging and purging for 30 minutes, purge ten well and sand pack volumes from the well using either a pump or a bailer. Test the purge water for pH, specific conductivity and temperature at regular volume intervals.

G. If purge water handling becomes a problem, or if the time required to purge ten well volumes becomes great, well development may be shortened at the discretion of the project hydrogeologist. However, pH and conductivity measurements should be stabilized, and a minimum of five well and sand pack volumes should be removed.

H. If a pump is used for purging, it should be set with the intake at the well bottom. A Keck pump or a Bladder pump should not be used for well development by itself because it does not pump at a high enough rate to remove sediment.

I. At the end of purging, measure the depth to water and the total well depth.

J. Record the relative recovery rate of the well; such as: very fast, or 10 ft in 60 seconds, or full recovery in 25 min.

K. Collect well development samples (if necessary)

1. If drilling fluids were used and if the well is at a solid waste facility in Wisconsin

    a. Total suspended solids - 500 ml unfiltered

    b. COD - 250 ml unfiltered, sulfuric acid preserved

2. Other project specific goals may require post development sampling, but generally sampling should wait until aquifer conditions have stabilized.

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IV. METHOD FOR WELLS THAT CAN BE PURGED DRY

A. A well which purges dry is one that can be bailed or pumped down to the bottom and does not recover 50% of this volume within 30 minutes. Plan to develop these wells first to allow recovery time.

B. Such wells should not be surged with a surge block: Limited surging with a bailer may be performed to remove sediment from the well bottom.

C. Follow III A through D (Method for wells that cannot be purged dry).

D. Slowly purge the well using a pump or bailer. A Keck pump or a bladder pump may be used, however these pumps do not handle sediment very well.

E. Test for pH and specific conductivity at the end of each well plus sand pack volume.

F. If possible, remove three to five well and sand pack volumes and monitor pH and specific conductivity. Return trips to the well on the same day, or overnight may be necessary.

G. Record the relative recovery rate of the well; such as 10 ft in 30 minutes, or full recovery in 90 minutes.

H. At the end of purging, measure the depth to water and the total well depth.

I. Collect well development samples (if necessary); See III. K above.

V. DOCUMENTATION

A. Monitoring Well Development Summary - See Attachment

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B. Waste Management Inc.

1. Monitoring Well Construction Summary

2. Record method of surging and purging, time spent developing and volume purged

3. Record time, pH, specific conductivity and temperature

GFP/ndj/______
[mad-sop-098]
12350/60000

Section Well Installation and Testing	Section No. 208	Date of Issue June 1994	Reviewed By T. Karwoski
Subject Extraction Well Development	Page 1 of 4	Date Revised	Authorized By K. Quinn

Scope and Application: This SOP is for the initial development of extraction wells.

References: Groundwater and Wells (Driscoll, 1986).

Procedures

The general procedure for effective development is:

- Begin surging the well with a surge block until sediment production goes down.
- Go to air jetting.
- Go back to surge block or pumping.
- Alternate between surge block, pumping, and jetting.
- Finish by pumping.
- Check and record specific capacity (pumping rate/drawdown in gpm/ft).

The specific procedure for development is:

1. Before beginning development drop a bailer to the bottom of the well and then pump it (quickly raise and lower) to check for sediment. If the well bottom or sump is full of sediment, remove it before starting development (e.g. use a pump installed into the sump or use a bailer).

2. Retain a sample of water and sediment removed from the bottom of the screen. This will be used to document the size fraction of material in the well before development. If development results in breaking the screen (e.g. dropping a string of tools to the bottom, breaking a weld on the base, etc.). allowing coarser grained sediment to come in, this sample would document this coarse grain size was not present before development.

3. Start development with a valved surge block to remove the fines in the immediate vicinity of the screen. The surge block gasket should fit firmly in the well (no space between well casing and gasket, but not so tight to be too difficult to remove). The valve on the surge block should be closed for wells in high permeability sand and gravel. This will allow water and sediment to move upward through the block, but not downward.

   However, in lower permeability soils, opening the valve may be required to allow moving the surge block.

Surge Block Operation:

- Use of a rig with a hydraulic head is more effective with a surge block than with a cable tool rig where the weight of the rod and string only forces the tool down.
- Drillers must check and mark on the rig, the point where the top of the drill rod would put the surge block at the bottom of the well screen.
- Do not lower the surge block into the casing sump below the screen unless the valve is opened or the gasket is loose enough to allow flow past it.
- Start at the bottom of the well screen, raising and lowering the surge block in approximately 2 ft strokes.
- The surging should pull water and sediment into the well on the upstroke. On the downstroke, some sediment and water is forced up through the check valve and some is forced out of the screen. This action loosens the sediment outside the screen and pulls it in on the upstroke.
- Continue operation from the bottom to the top of the screen.
- Contain sediment produced as necessary.

- Collect a sample of sediment once during development and once on completion to compare back to the original, pre-development sample to check for effectiveness of development and for possible screen damage. Note on development form:

  - Grain size, especially note any grains coarser than installed screen size.
  - Color, especially any black or gray bacterial matter (generally only on wells being re-developed).

4. Surging should be followed by air jetting. A jetting tool typically consists of a set of horizontal nozzles, slightly smaller than the well diameter. A dual tube arrangement is available from some contractors that allows jetting through the nozzles or to act as an air lift pump when redirecting the air up the center tube. However, air lift pumping requires approximately 40% to 60% submergence (i.e.(depth below water/total depth)*100) which we typically do not have, except in very shallow groundwater conditions. Pumping at <40% submergence is possible but air is also blown out the bottom of the dual tube.

Air Jetting Operation:

- The objective of air jetting is to apply a large force on the screen, sand pack, and formation to loosen encrustation, precipitates, and sediment for later removal.

- Because an air jet only applies force outward from the screen it is imperative that it be used with another method to pull water and sediment back into the well for removal.

- A dual tube - air jet/air lift pump can do this if submergence conditions are favorable.

- Air jetting should be started with straight air, some water can be injected later for additional force if air alone is not successful.

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- Jet each zone of the screen while rotating the nozzles to get full coverage.
- Alternate between jetting and pumping as often as practical but do not jet for more than 3 minutes per foot of screen without pumping.
- After jetting a zone, pump as soon as possible but not more than one hour after jetting.

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Appendix C

MONTGOMERY WATSON

APPENDIX C

PUMP TEST
STANDARD OPERATING PROCEDURE

Section Well Installation and Testing	Section No. 205	Date of Issue June 1994	Reviewed By T. Karwoski
Subject Pumping Tests	Page 1 of 8	Date Revised	Authorized By

Scope and Application: This SOP is for pumping tests in vertical well with water level monitoring at observations wells using pressure transducers and data loggers.

References: Chapter 2 - Pumping Tests ~~of~~ Analysis and Evaluation of Pumping Test Data by Kruseman and DeRidder.

OBSERVATION WELL LOCATIONS AND THEORY

The number of observation wells required for a pumping test depends on the amount of information required. Kruseman and DeRidder (1991) recommend a minimum of three wells so data can be analyzed by both time drawdown and distance drawdown methods.

The distance an observation well is placed from the pumping well depends on the type of aquifer and its transmissivity, duration of pumping, discharge rate, length of well screen, and stratification or fracturing within the aquifer. Generally, wells should be placed so data would be uniformly spaced on a logarithmic scale (e.g., 10, 25, 50, 100, 225). The actual design of the pumping well and monitoring network should be based on a preliminary analysis using a simple well hydraulics equation (e.g., Theis equation) and general information about the aquifer geometry and hydraulic conductivity. For more specifics on observation well placement, refer to pp 33-36 of "Analysis and Evaluation of Pumping Test Data" (Kruseman and DeRidder, 1991).

The depth of the piezometers is also dependent on the type of aquifer. In an isotropic, homogeneous aquifer, the center of the piezometer screens should be placed at the same elevation as the center of the pumping well screen. In heterogeneous, layered aquifers, nests of piezometers and screens intersecting the highest conductivity layers are desired.

PRE TEST PREPARATION

Pumping Test Field Equipment

1. Work Plans and Health and Safety Plans
2. Special field instructions (optional)
3. Electric water level indicator(s)
4. Oil interface probe (if floating oil present)
5. Hermit data loggers(s) - 2-channel and 8-channel
6. Pressure transducers - 1 for the pumping well and each observation well
7. Pressure transducer protectors or hazardous waste pressure transducers
8. Submersible pump (to include all plumbing equipment)
9. In-line totalizing flow meter(s)
10. Sufficient hose or pipe to discharge water outside of test area or to tank/sewer etc.
11. Well head flow meter
12. Time piece (digital)
13. Barometer
14. Electricity supply for well pump (2 or 3 phase depending on pump)
15. Fixed and portable lighting with electricity supply
16. Field computer (to include a spread sheet and AQTESOLV)
17. Groundwater sampling equipment (optional)
18. 2 - 5 gallon bucket
19. Tool box
20. First aide kit

Data Logger and Transducer Evaluation and Programming

The data loggers (2-channel and 8-channel) and transducer(s) to be used to collect data during a pumping test must be evaluated for functionality, accuracy, and drift sufficiently in advance of starting to collect data in order to replace defective transducers. Four days is recommended.

Subsequent to completing the data logger and transducer evaluations each data logger should be programmed for the collection of background water level data. Follow the instructions in the In Situ data logger manuals for the 1000 (2-channel) and 2000 (8-channel) data loggers. Select linear sampling and set the water level sampling rate at one recording every 15 minutes. The "Type" and "Mode" will be

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Subject Pumping Tests	Page 3 of 8	Date Revised	Authorized By

set to Level and TOC, respectively, Transducer parameters "SG" and "Delay Msec" will be set to 1.0 and 50.0, respectively. Transducer parameters "linearity", "Scale Factor", and "offset" will be set to the values that are printed on the data tag attached to the transducer cable reel. Use the quadratic coefficients for the linearity. The reference value is the only transducer parameter that must be set in the field. The reference should be set to 0.0 after each transducer has been placed below the water table and the water table has been allowed to stabilize and the temperature of the transducer has been allowed to equilibrate with the current groundwater temperature.

Baseline Data Acquisition Phase of Pumping Test

Pre-pumping test water level, precipitation, and barometric pressure data should be collected for five days in advance of the pumping test. The following field activities are to be performed, in this order, during the first full day of field activities.

1. Collect a complete round of water level measurements.

2. Install the rain gauge and a digital or analog barometer at the pumping test site. Barometric pressure and precipitation will be recorded once each day during the collection of background data. Initial barometric pressure and precipitation readings will be collected at the end of the first full day of field activities.

3. Install transducers in pumping test wells per the Work Plan and field instructions prepared for the site (construct transducer cable protectors, if needed).

   The 8-channel data logger will be used to monitor water levels in as many designated wells as possible. Two channel data loggers will be used to monitor water levels in a well(s) that has/have been designated background. Depressing XD on the data logger as the transducer is lowered down the well will show depth (in feet) below liquid surface. Pressure transducer total depth (TOC) can be determined by adding the XD value and the current depth to liquid (TOC) measurement. When the transducer has been set to the appropriate depth it will be necessary to monitor the XD values for the transducer in order to determine if the static water level has equilibrated. Equilibration will be considered complete when the XD value remains constant to within ±0.02 feet. Also, because transducer readings can be adversely affected by changes in transducer temperature it is imperative that each transducer be allowed to temperature equilibrate with the groundwater for up to 0.5 hours.

After equilibration, set the reference for each transducer to 0.0 and start the data logger. Monitor the data logger by using the view function (refer to pocket guide or manual) for one hour to ensure that the logging equipment is functioning properly.

4. Check the data logger(s) and transducers periodically during the collection of this preliminary data to see that the equipment is functioning properly and to begin plotting and reviewing water level, barometric pressure, and precipitation data. Frequency is dependent on the cost to check vs the cost to lose data and the data quality control needed. One check at the beginning, middle, and end of a 5-day baseline period is generally sufficient. This will require downloading of water level data from the data loggers with a laptop computer (following the instruction contained in-Situ's instruction manuals) and manually collecting a complete round of water levels from pumping test wells. Data values collected for each transducer should be reviewed in order to verify that:

   - The data logger is sampling at the defined sampling rate.
   - The transducer drift is within acceptable tolerance (±0.01 ft)
   - Changes in water level are recorded within acceptable tolerance (±0.01 ft)
   - If the data logger(s) and/or transducer(s) are malfunctioning, replace with a spare. If a spare is not available, contact the project manager immediately.

   Barometric pressure and precipitation measurements should be recorded at least once per day, obtaining hourly records from the nearest recording.

5. Preliminary data collection will be terminated for the 8-channel data logger, typically when the step test or pumping test is to be started. Follow the instructions In-Situ manuals and pocket guides for terminating a test. The background data logger should continue to collect background water level data.

Step Test (Optional)
A step test may be conducted the same day that preliminary data collection is terminated. The purpose of the step test is to determine the maximum pumping rate sustainable by this well. At least three pumping steps are recommended, each lasting 1 to 2 hours. The test can be performed in one day but should be completed at least 24 hours prior to the planned start of the constant rate pumping test to allow time for the water table to recover to near static conditions (12 to 24 hours).

Water levels through time in the pumping well and its pumping rate are the only data needed for the step test. However, this test also allows a final test on pressure transducers in wells near the pumping well.

The pumping in the well is started at a rate of about ⅓ its estimated maximum. Water levels in the pumping well are recorded on about a two to five minute interval.

Drawdown from static is plotted through time. When steady state conditions are reached (i.e., very little additional drawdown is occurring) the pumping rate is increased to the next step.

If drawdown continues to increase, without approaching steady state, and it appears this will dewater the well before the length of time desired for the pumping test, a lower pumping rate should be selected. Caution should be used that a true steady state is reached at this lower rate as opposed to simply a reduced rate of drawdown.

The rate for the pumping test should be determined during the step test to be the highest rate possible that will not dewater the well during the test. The pumping rate should be adjusted to that rate so no adjustments are needed during the critical early time of the pumping test.

Pumping Test

Following completion of the step test or background data collection if no step test is conducted, the 8-channel data logger should be reprogrammed for the pumping test following the instructions in the In-Situ manuals and pocket guide. The data logger should be set for Top of Casing (TOC) mode and logarithmic sampling intervals with conversion to linear sampling at 5 minute intervals after log cycle 4 (refer to In-Situ manuals). Water levels in the aquifer also must be allowed to recover to near pre-step test conditions (within 0.03 ft), allowing for changes in background water levels). This typically will require a 12 to 24 hour period of time.

The reference for each transducer (except those in background wells) should be set to 0.0, start the data logger, and then start the pump (record start time).

The flow rate must be periodically monitored by observing both the in-line and well head flow meter readings and by performing one or two bucket measurements. Bucket measurements are made by recording the time required for the pump discharge to fill a 5-gallon bucket. The rate is then converted to gallons per minute. Carefully make <u>minor</u> pumping rate adjustments as needed to maintain a constant pumping rate. Record actual pumping rates and time of reading.

Manual collection of water levels in pumping test observation wells should be collected at a minimum of 5 times during the test for transducer measurement quality control.

Time and depth to water will be recorded on the forms attached to this document.

Data should be downloaded from the data logger every six to eight hours using the laptop computer, In-Situ's data transfer program (or Kermit) and following downloading procedures detailed in In-Situ's data transfer manual. <u>Be careful to do this</u> without erasing the previously recorded data.

Arrangements should be made with the project hydrogeologist for data transfer (e.g., sending as ASCII file via the VAX and/or on floppy disk overnight mail). A detailed shift report should be maintained for each of the shifts and submitted to the project hydrogeologist on a daily basis (FAX) to include:

- Manual water level measurements
- Associated transducer readings and the time of measurement
- Pumping rate checks and time of check

Downloaded data should be reviewed for quality and consistency and to determine when the full scale pumping test should be terminated and the recovery test initiated.

Recovery Phase
Prior to initiating the recovery phase of the test a final data download must be performed. To initiate the recovery phase the "STEP THE TEST" key sequence (described in the In-Situ manual) should be executed. Simultaneously, the FI key should be depressed (will initiate data collection by the data logger and transducers for the recovery phase) and the pump turned off. Record the time when the recovery phase initiated. Manual water level measurements should be collected from each observation well on the same schedule as during the pumping test for transducer quality control should be monitored (remember that data cannot be viewed until log cycle three is complete).

When pre-pumping test static water level conditions are approached in the pumping well, the recovery phase of the test may be terminated. Stop the data loggers and demobilize from the site. The data loggers should be returned to the office for data downloading into a file on the hard drive of an office personal computer since the file containing the data can be large. Follow the download instructions in In-Situ's Data Transfer Manual. The downloaded data should be copied to a 3.5" high density floppy (compress with PKZIP if necessary) which is to be provided to the project hydrogeologist.

Data Evaluation
After completion of all four phases of the pumping test (background, step-test, constant rate test, recovery), the following procedures should be followed to perform data analysis:

1. Download the data onto a PC computer by following the directions in the data logger manuals.

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2. Make at least one extra file copy of the raw data before erasing the data logger entries.

3. Create a working copy of the files and transfer them into "Excel" Spreadsheet format. (.XLs). Parse the data into time and drawdown columns.

4. Plot the background, constant rate, and recovery data on log and semi-log scales.

5. Review the plots for the following:

   - Instrument drift (compare each plot to background well plot).
   - Unidirectional variation (influences by natural recharge or discharge).
   - Rhythmic fluctuations (aquifers can be influenced by changes in tides, river levels, atmospheric pressure).
   - Non-Rhythmic Regular Fluctuations (changes in barometric pressure).
   - Unique fluctuations (heavy rainfall, sudden rise in river levels). Refer to pp 47-48 of Analysis and Evaluation of Pumping Test data (Kruseman and DeRidder, 1990) to determine how to correct for these data variations.

6. Interpretation of the data can now be performed. There are many methods which may be applied to interpret a pumping test. The specific methods applied to any one test depend on:

   - Aquifer type
   - Well response
   - Boundary conditions

There are several published methods in Kruseman and DeRidder (1990) as well as in the "AQTESOLV" Software.